GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

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Subscription Rates: United States and Mexico, $3.00 per year; Canada, $3.25 per year; Foreign, $3.50 per year; payable in advance. *Library and Student Rates:* United States and Mexico, $2.00 per year; Canada, $2.25 per year; Foreign, $2.50 per year; payable in advance.

Remit by post-office or express money order, bank check, or draft, made payable to the *General Electric Review*, Schenectady, N. Y.

Advertising forms close on the first day of the month preceding date of issue.

Entered as second-class matter, March 26, 1912, at the post office at Schenectady, N. Y., under the Act of March, 1879.

Vol. XXVII, No. 1

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JANUARY, 1924

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The Venetian Lamplighter

The Fifth of a Series of Paintings Portraying the Development of Light

Painted by Maxfield Parrish for the Edison Lamp Works of the General Electric Company

FOUR years ago, Maxfield Parrish, America's master of color, undertook this series of paintings portraying the development of Light. Beginning with a dramatic painting of Prometheus, who stole fire and light from the sun for the benefit of mankind, thereby incurring the enmity of the Olympic gods, Mr. Parrish in successive paintings followed the trail of Light through prehistoric days, into ancient Egypt, and then to the Arabia of the Middle Ages.

With the Renaissance, Europe won back the Torch of Progress. The oil lamp of clay became a lantern, glassed to shield the flame. Streets, as well as homes, were lighted to guide the wayfarer and to protect burgher and guildsman against thieves.

And so this year, Mr. Parrish brings us to Venice, center of the art, learning and trade of the Middle Ages. Venice under the Doges! When half the year was spent in carnival; when prince and pauper, merchant and maidservant, masked and costumed, joined in frolic together.

Mr. Parrish shows us a Venetian lamplighter in his gondola, slipping silently through the canals at sunset, to light up the piazzas and quays for the nightly carnival; and to touch the waterways with the magic light that inspired the love songs of the gondoliers.

* * * * *

It was on October 21, 1879, that Thomas A. Edison first set a carbon filament aglow with an electric current and so revolutionized artificial lighting. In the intervening forty-five years, more progress has been made in the art of lighting than in all the centuries since Venice was at the height of its glory.

And still the progress continues. In the Research Laboratories of the General Electric Company, which developed the present MAZDA Lamp, scientists are ceaselessly searching for better and still better light at a lower cost. By virtue of this research, the most efficient lamp of tomorrow, like the most efficient lamp of today, will bear the pioneer name and service mark—MAZDA.

© E. L. W. OF G. E. CO

PAINTED BY MAXFIELD PARRISH

THE VENETIAN LAMPLIGHTER

With Good Wishes for 1924
from the
REVIEW

GENERAL ELECTRIC REVIEW

NEIGHBORS

In our January issue which comes off the press at Christmas time we always like to wish our friends and neighbors a Joyous Christmas and a Happy and Prosperous New Year. We express these heartfelt sentiments to you all.

At the Christmas season it is a habit of the mind to look back on the *good old days*, and so we send our season's greetings to our friends on cards decorated with pretty pictures of stage coaches, smiling peasants in smock frocks and bold highwaymen. There is a strange philosophy in this habit. It portrays, more often unknowingly, that peculiar fact that in each age, as society eagerly and laboriously struggles forward, it still persists in looking backward with tender regret.

We are living in an age of great material progress and this habit of mind strengthens the belief of the mentally blind and the chronic pessimist that our progress is material only. So, as a technical paper that makes a practice of recording our material progress, we think it right at this Christmas season to say that our progress is moral and intellectual as well as material, and, moreover, to note that it is our material progress that is leading us forward both morally and intellectually as well as carrying these advancements to every corner of the globe. Modern science is making neighbors of us all.

There are two perfectly definite reasons why material progress, as exemplified by the application of scientific knowledge to the details of everyday life, should lead to moral and mental development—(1) When any science becomes an experimental science, and especially when it becomes the subject of industrial research, it tends toward perfection. (2) There is in every human being a strong desire to better himself.

Lord Macaulay, in his history of England, after noting, in somewhat different language, these two great truths goes on to say "These two principles have often sufficed, even when counteracted by great public calamities and by bad institutions, to carry civilization rapidly forward. No ordinary misfortune, no ordinary mis-government, will do so much to make a nation wretched, as the constant progress of physical knowledge and the constant effort of every man to better himself will do to make a nation prosperous. It has often been found that profuse expenditure, heavy taxation, absurd commercial restrictions, corrupt tribunals, disastrous wars, seditions, persecutions, conflagrations, inundations, have not been able to destroy capital as fast as the exertions of private citizens have been able to create it."

We have never read a stronger argument than the above against those who, misguided by religious superstition, political fanaticism, unwarranted jealousy or ignorance, would limit individual effort; and in the limiting retard our moral and intellectual, as well as our material, progress.

After all is said and done applied science is the greatest civilizing influence in the world. Since we have depended on science rather than dogma for progress we have advanced many fold more in each decade than we did in each century before. Each new invention that knits society closer together, and eliminates distance as a stumbling block to better understanding and facilitates the spreading of education and knowledge, is in itself a factor in building civilization. Macaulay expresses this truth in his usual forcible and convincing language in the following paragraph:

"The chief cause which made the fusion of the different elements of society so imperfect was the extreme difficulty our ancestors found in passing from place to place. Of all inventions, the alphabet and the printing press alone excepted, those inventions which abridge distance have done most for the civilization of the species. Every improvement of means of locomotion benefits mankind morally and intellectually as well as materially, and not only facilitates the interchange of the various productions of nature and art, but tends to remove natural and provincial antipathies, and to bind together all the branches of the great human family."

After the disastrous expenditures of the Napoleonic wars it was the wealth created by applied science that rehabilitated Europe. The development of steam railways and other modes of transportation created new wealth and stimulated individual effort to a far greater degree than war had destroyed them.

But some still persist in looking back with tender regret on the *good old days* and are blind to the moral and intellectual force of modern improvements. The supposed modern social evils are old evils, not new, and as Macaulay so aptly says "that which is new is the intelligence which discerns and the humanity which remedies them."

The character of the mass of men composing the great human family has changed, and it is the work of the scientists, specially in developing rapid means of communicating intelligence, that has wrought the change. Man is incomparably more humane than he was—the mass is inconceivably better educated. The conditions of living are infinitely better.

Who would go back to the day when labor was told to make bricks without straw? Do our pessimists forget the torture chamber, the filth and pestilence of the dungeon, the squalor of the streets and the dirt and disease of the poor man's dwelling?

To say we are not advancing morally and intellectually is foolish—and only displays ignorance of the past; but what is of equal importance—do our optimists even realize how rapid the change in man's character has been because of our material advances?

Awakened by that great stir in the human mind, known as the Renaissance or revival of learning, the spirit of Francis Bacon and the transcendant genius of Isaac Newton lifted the minds of men to higher and greater thoughts; since then our advances in science have gone on at such a pace that few realize the extent of the change, or trace the cause.

It is too large a picture to paint and too long a chapter to write, so to give some small idea of this rapid change in character let us quote a few paragraphs from Macaulay, written concerning this period, in that illuminating chapter of his styled, "The State of England in 1865."

"Whigs were disposed to murmur because Stafford was suffered to die without seeing his bowels burned before his face."

"Tories reviled and insulted Russell as his coach passed from the tower to the scaffold in Lincoln's Inn Fields."

"If an offender was put into the pillory, it was well if he escaped with life from the shower of brickbats and paving stones. If he was tied to the cart's tail the crowd pressed round him imploring the hangman to give it the fellow well, and make him howl."

"A woman burned for coining excited less sympathy than is now felt for a galled horse or an overdriven ox."

"Multitudes assembled to see gladiators hack each other to pieces with deadly weapons and shouted with delight when one of the combatants lost a finger or an eye."

This was written of the middle of the seventeenth century.

Who was my neighbor then?
Who is my neighbor now?
Think of the Japanese disaster!

Science could not develop without intellect and intellect has not developed without improved morals. Man has become more humane because he is more moral and more scientific because he is more intellectual. Because man has grown more moral and more intellectual he has developed a finer character, and because he has developed a finer character he has an undying desire to be of service to his fellow beings.

The common desire to be of service is the product of a more moral and more intellectual age. The opportunity *to do something* is more valued than the chance *to be some one*, and works outrank honor, in the epoch of more highly developed character. Hand in hand with the spirit of service discontent is growing; but this is mysterious alone to those who misunderstand and misinterpret the virtue of discontent. The day that man becomes satisfied with himself, and contented with his lot and surroundings, progress will cease. When reason and added effort are used in place of force to bring about desired changes discontent spells progress. An increase in intelligence can never lead to contentment—but can, and does, and should stimulate effort to better conditions. Those who neglect to recognize these truths must be bewildered at the present and skeptical of the future.

It is always harder to visualize the present, or speculate on the future, than it is to comprehend the past; but since the world war mighty airships have crossed the broad expanse of the Atlantic, and heavier than air machines have flown the vast airways connecting its far flung shores. In Europe the sky has become criss-crossed with aerial passenger routes, and in America the wide continent between the shores of the Atlantic and Pacific is crossed daily by the United States mail through the uncharted sky. Speeds that were undreamed of have become realized. Distances have been correspondingly abridged. And, again, science has made neighbors of us all.

It is not so long ago that man was marveling at viewing the leg of a flea through a microscope and actually seeing a microbe—this was indeed prying right into the secrets of nature; but with the swift development of character and intelligence man did not rest content. The greatest wonder of the age has come through the high intellect, and profound and patient character, of such unparalleled geniuses as J. J. Thomson, Rutherford, Bragg, Bohr and Langmuir who dared pry right into the ultimate secret of matter's composition. It was intellect that led to the profoundest of all discoveries—that the very atom itself was composed of positive and negative particles, and indeed that all matter is composed of such charges, and that it is the difference in their number and arrangement which determines the nature of all elementary substances.

The story of this work is far too long to write, but men have not only weighed the atom, but weighed, measured, and computed the speed of the electron and the ion. They have named them, have classified them and known them.

The boldest mind hardly dares to speculate where this work of science will lead us mentally, morally and physically.

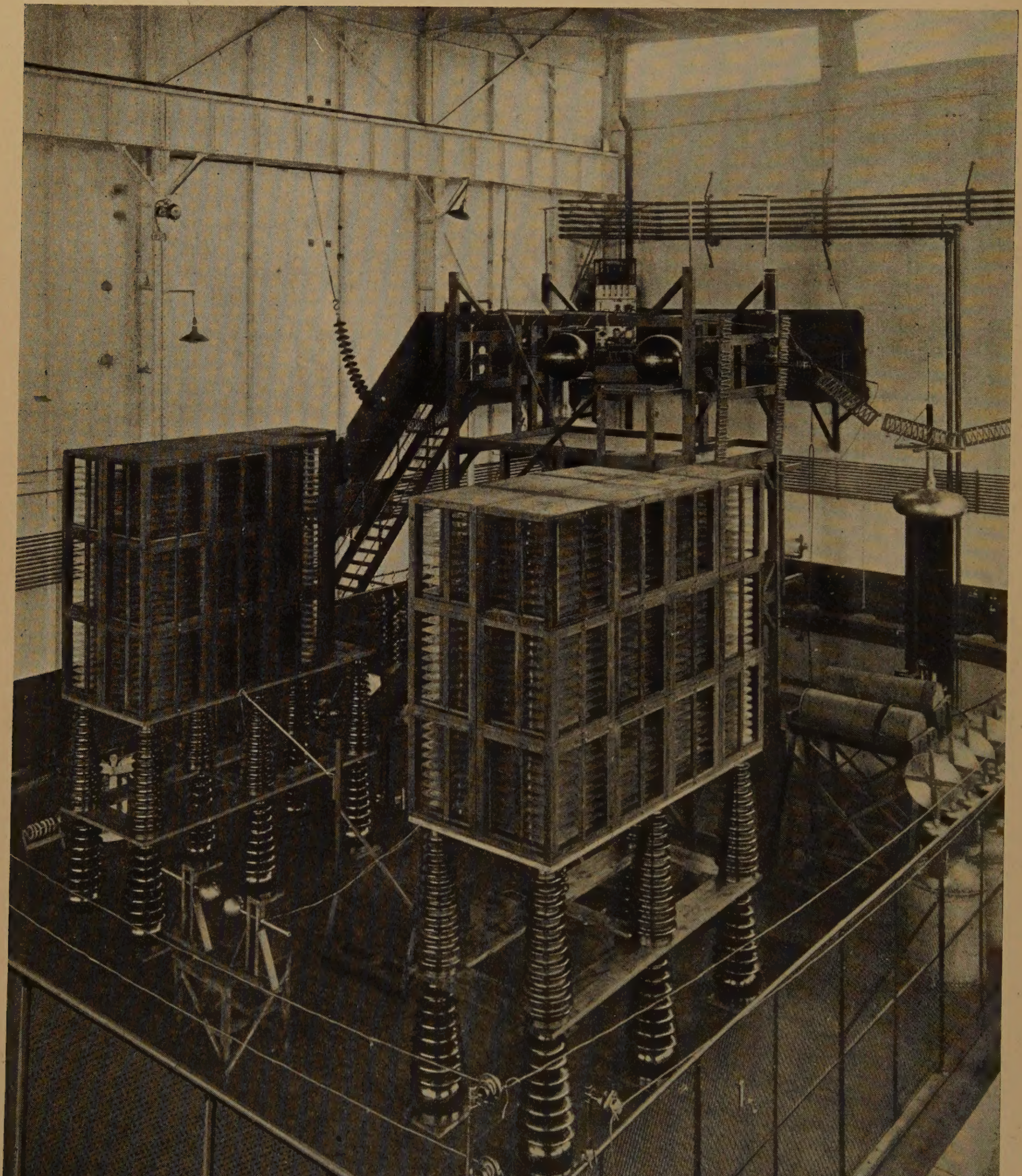
One of the first fruits of this work is that little thing called the *electron tube* or *electric valve* which has turned the vague promises of wireless communication into an accomplished fact. Modern wireless, both wireless telegraphy and wireless telephony, are based on this. By this work modern broadcasting has been made possible. The energy of youth has been directed to science through amateur wireless, and the wide world has, as it were, been brought under one roof.

Today it is physically possible for the whole world to listen to one man speaking in any corner of the globe. It is the greatest advance ever made in the rapid exchange of intelligence—distance has been wiped out.

In the future it will, by mutual helpfulness and common understanding, curtail wars and promote peace, spread education and stimulate learning and make neighbors of us all.

The Spirit of Christmas is the Spirit of Science—Peace on Earth Good Will toward Men.

J. R. H.



Lightning Generator, in the High Voltage Engineering Laboratory of the Pittsfield Works, used for testing apparatus designed for protection against lightning. See page 36.

Some Developments in the Electrical Industry During 1923

By John Liston

Publicity Department, General Electric Company

We again report in our January issue the progress made in the preceding year. Until we collect our data in this form, we cannot appreciate the measure of our progress; but any one who reads this article will perceive that we took long strides along the path of progress in the year 1923, and that a host of developments and inventions in legion directions is leading us irresistibly forward.—Editor.

Throughout the electrical industry the year was characterized by a record volume of production in practically all classes of apparatus, exceeding in many cases the maxima of wartime output. The demand for electrical apparatus showed seasonal irregularities, but manufacture proceeded almost uniformly at a high rate.

High pressure production is not usually conducive to radical changes in design and a considerable proportion of the improvements made were along conventional lines. There were, however, a number of distinctly new developments which represented advances in the art, some of which were fully commercialized while others were still being subjected to experimental test at the close of the year.

The recent tendency toward increased unit capacity continued in evidence. The 62,500-kv-a. turbine-generator, Fig. 1, the first of the two 65,000-kv-a. waterwheel generators, and a synchronous converter of record size were completed, while various types of transformers exceeded the record unit ratings of previous years.

In transportation, electric propulsion was for the first time applied to large cargo craft for canal service and improvements were made in auxiliary ship equipment. The more important railway developments occurred in foreign countries as in the preceding year and the high voltage direct current system was utilized to a large extent for main line steam railway electrification. In street railway service, there was a further adoption of the economical light weight double truck car.

The use of automatic stations was extended to new industrial fields and initial foreign

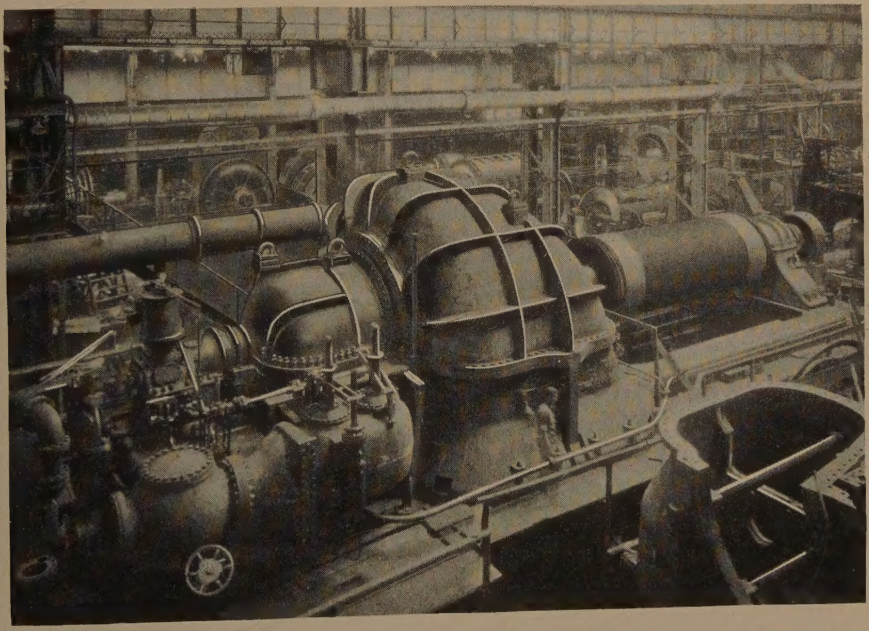


Fig. 1. 62,500-kv-a., Single-cylinder, Steam-turbine Generator Undergoing Shop Test

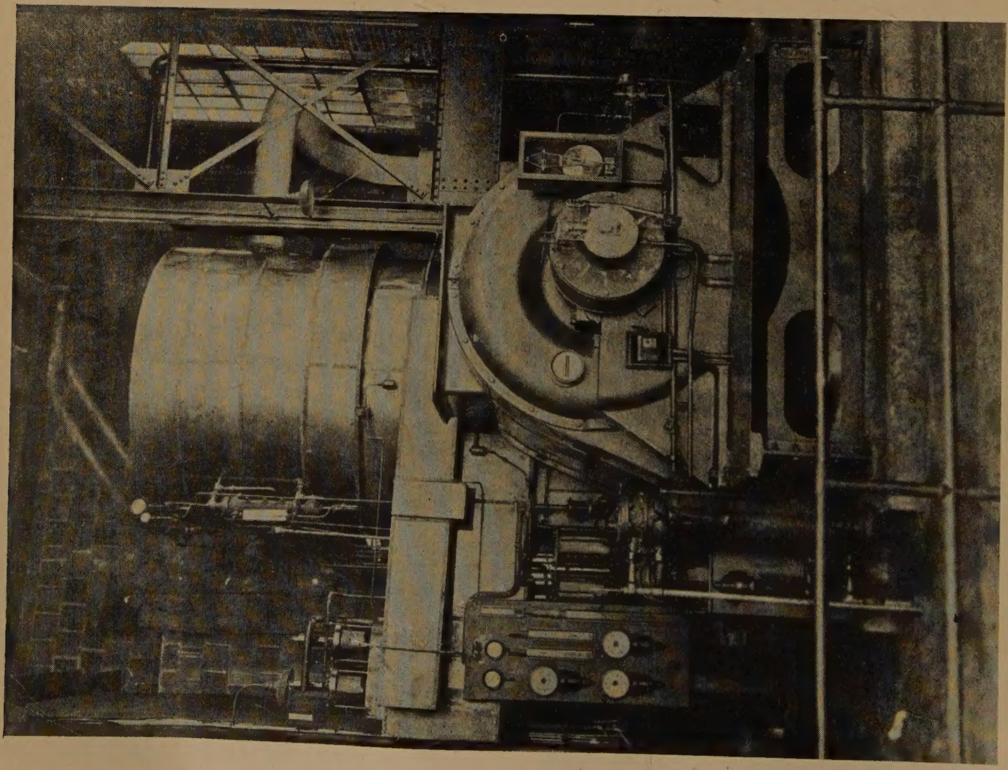


Fig. 2. Mercury Boiler and Turbine in Hartford Electric Light Company Power Station

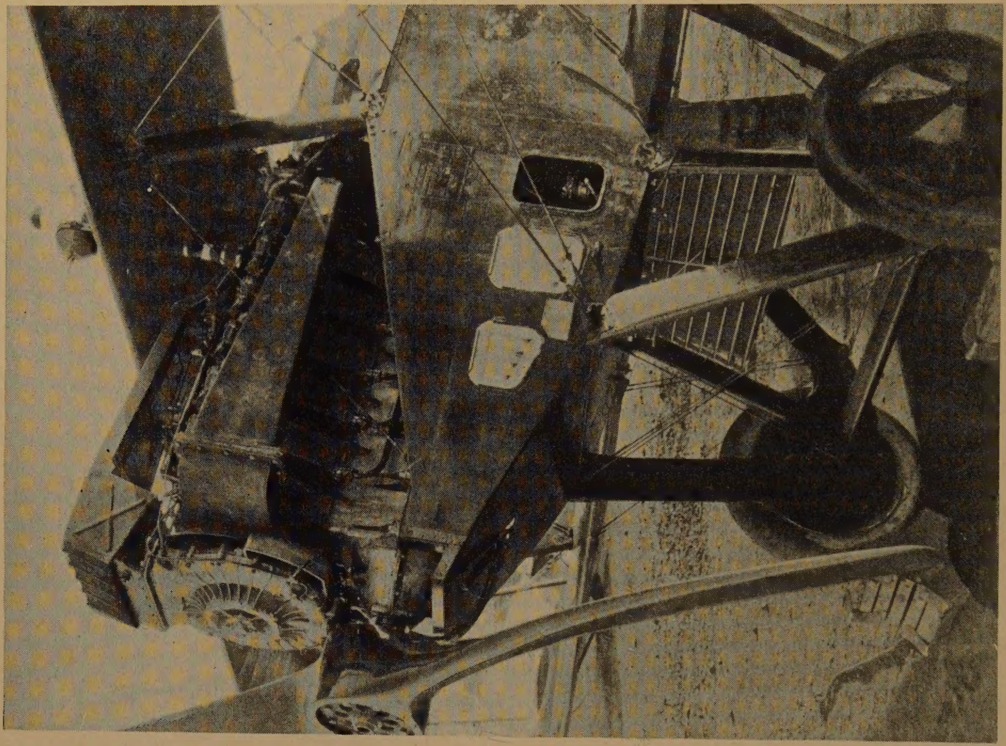


Fig. 3. New Type of Airplane Supercharger

installations were made. Few radical changes occurred in either the design or construction of the equipments but the number installed and their unit capacity were greatly increased.

For radio service new tubes were developed of both higher and lower power than any previously produced and all sizes were improved in efficiency by the use of a new filament which gives high electron emission with low current consumption. Interesting, and potentially important, experiments were carried on with vacuum tubes for purposes other than communication, and carrier current telephone systems of increased range and power were used successfully on a number of power lines.

Investigations in high potential phenomena were continued with the lightning generator, high voltage direct current testing sets and X-ray tubes of great power were developed, the photo-electric cell was practically applied in the operation of a commercial machine and a complete new line of electrically operated flow meters was standardized.

Higher efficiencies were achieved in the design of several types of industrial motors as compared with previous practice and corresponding advances were made in the control apparatus to be used with them. The vast number of motor applications in modern industrial plants renders every detail improvement secured in the operation of individual motors of great potential economic value when considered in the aggregate.

As in previous articles on this subject, the electrical apparatus, turbines, etc., referred to, are all products of the General Electric Company, but references to their development will serve as an indication of the tendencies in design and construction as well as the general trend of progress in the electrical manufacturing industry as a whole.

TURBINES

Developments during the year on large turbines consisted of refinement in mechanical details without radical changes in construction. The outstanding features were the production of turbines for high steam conditions and the production of turbines in unprecedented volume.

Shipments for 1923, exclusive of turbines for mechanical drive and ship propulsion, had a total capacity of approximately 1,660,000 kw. This was an increase of 85 per cent over the average for the preceding five years and an increase of 32 per cent over the maximum wartime production in 1917.

The first of the 35,000-kw. turbines designed for 550-lb. pressure and 750 deg. F. total steam temperature was completed and shipped while four of the same capacity and one 60,000-kw. compound unit to operate under similar steam conditions were under construction. It is confidently expected that the installation of these units will result in a substantial reduction in operating costs as compared with previous practice.

The solution of the problem of lower operating costs is being approached in two other ways. The first commercial equipment, Fig. 2, which includes a mercury boiler and turbine exhausting into a condenser boiler which in turn generates steam for an existing steam turbine station was put in service in the fall of 1923. The results which have been obtained confirm experimental tests and there is every reason to believe that this development will be of great value in reconstructing many existing stations.

In addition to this there were under construction one 2600-kw. and one 4000-kw. turbine designed for a steam pressure of 1000 to 1200 lb. and to exhaust into headers supplying other turbines at from 250 to 350 lb. These machines are an entirely new departure and involve special boiler equipment. The turbines, however, are simple in design and present no obstacles to the ultimate success of the system adopted.

The 50,000-kw., 62,500-kv-a. single-cylinder turbine direct connected to a single generator, mentioned last year, was manufactured and shipped.

While not so impressive or spectacular as the work on large machines, the development and standardization of a complete line of new turbines up to and including 6000 kw. is of great importance. This work was not completed but machines so far built and tested have met expectations in every respect.

SUPERCHARGER

A new turbine supercharger for airplanes, Fig. 3, was designed and built specifically for extreme altitude operation. It is rated to feed sea level atmospheric pressure to the engine at a height of 35,000 feet, or about twice the rating of the one used in the previous American altitude record flight.

The supercharger consists of a turbine compressor mounted just back of the propeller blades of the plane on the front end of the Liberty motor and is operated from the red hot exhaust gases from the airplane motor, which ordinarily go to waste. It weighs about

140 pounds which might be considered a handicap in altitude flying but for the fact that at 35,000 feet its operation will increase the power of the Liberty motor by at least 280 horse power, or about two horse power for each additional pound carried.

A supercharged plane at 1000 feet, making 126 miles per hour, can make about 150 miles at altitudes over 20,000 feet, whereas a plane without a supercharger can make 131 miles at 1000 feet but only 70 miles per hour at 20,000 feet. This shows that although there is a small loss in speed at low altitudes, there is a decided gain when flying at great heights.

The new supercharger has a rated speed of 33,000 r.p.m. but in tests it has been operated up to 41,000 r.p.m. or 683 turns of the compressor wheel a second, a speed probably greater than ever before attained in any commercial machine.

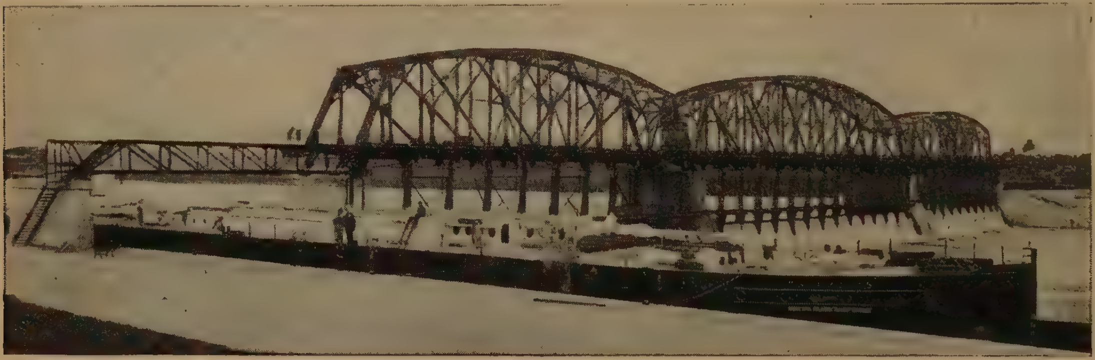


Fig. 4. The *Twin Ports* Passing Through Locks of the New York State Barge Canal

ELECTRIC PROPULSION

Diesel engine electric propelling equipments were adopted for two ships of a new type, built for refrigerating cargo service on the Great Lakes and New York State Canal System, and for coastwise trade to the West Indies during the winter. The first of these ships, the *Twin Ports*, Fig. 4, 258 feet overall and 42 feet beam with a full load draft of 13 feet and a cargo capacity of 2600 tons, started commercial operation in September.

The electrical equipment comprises two 250-kw., 230-volt, 260-r.p.m. direct-current generators direct driven by two Lombard-Diesel engines and two 250-h.p. motors direct connected to twin propeller shafts which give a speed of 10 miles per hour at full motor load. Contactor control panels are located in the motor room but the controllers for the two motors are installed in the pilot house or on deck to facilitate the handling of the ship in passing through canal locks or maneuvering in narrow or congested waterways.

All auxiliaries including steering gear, ventilation, capstans, winches, refrigeration and heating are electrically operated and their current supply is taken from the main generators while under way. When this supply is not available, a 40-kw. auxiliary Diesel engine driven generator is used.

The seven electrically propelled ferryboats referred to in last year's review are now in service after successful trials, and are showing excellent operating economies. One of these boats, the *Golden West*, running between San Francisco and Sausalito, which is rated as an 80-automobile boat and has Diesel-electric equipment, required 0.95 bbl. of fuel oil per running hour in comparison with a steam engine driven boat rated at 60-automobile capacity, on the same route and at the same speed, which consumed 3.35 bbl. per hour.

The resumption of work on the 180,000-h.p. equipments for the airplane carriers brought the first two of the 16-propeller motors through a successful shop test about the middle of the year. They are rated 22,750 h.p., 5000 volts, 3-phase, 60-cycles, 317 r.p.m., Fig. 5, and can be operated at 10 per cent overload without injurious heating. They are wound for 22 and 44 poles to insure high efficiency at both high and low speeds. At a cruising or maneuvering speed of 163 r.p.m. they develop about 6800 h.p.

There are many unusual features in the control apparatus provided for these ships; the most important being the use of contactors throughout for handling the generator output of 150,000 kw. at 5000 volts, 3-phase, 60 cycles, without oil switches or oil circuit breakers anywhere in the system.

At the close of the year there were G-E electrical propelling equipments completed or under construction for 14 ships, making the aggregate rating of this class of machinery, from 1908 to date, more than 550,000 shaft h.p. for 45 ships.

ELECTRIC RAILWAYS

Steam Road Electrification

As in the preceding year the more important additions to main line electrification occurred in foreign countries and it is noteworthy that in a majority of cases the 3000-volt direct current system was adopted.

Five switching locomotives, substations and distribution equipment were under construction for the Paulista Railway in Brazil, supplementing equipment previously supplied, which has been in successful operation for about two years. The new apparatus will take care of the extension of the present lines for a distance of 35 miles over grades similar to those on the section now electrified, but with single instead of double track line. These locomotives will weigh about 62 tons each and will be equipped with four 160-h.p., 1500/3000-volt motors and contactor control. Switching operations now being handled by steam engines will be taken over by the electric locomotives.

Progress on other electrifications included the initial operation of 3000-volt equipment on the Spanish Northern Railway in Spain; six locomotives having been made ready for service during the latter part of the year. Two substations were also completed for supplying 3000 volts direct current for the operation of this line.

Ten 150-ton, 3000-volt locomotives for the Mexican Railway Company, Ltd., Fig. 6, were completed and tested together with substation equipment, which will be ready for operation by the time the first locomotives are placed in service. In addition to the railway units the apparatus used in connection with this electrification includes waterwheel-driven generators for the Pueblo Tramway Light and Power Company, which will supply energy to the railroad.

Substation and car equipment was shipped to the Java State Railways on the island of Java in the Dutch East Indies. These lines are being electrified around the City of Batavia using 1500 volts direct current.

In connection with the extensive electrification program being put through by the Japanese Imperial Government Railways, two locomotives weighing 66 tons each were placed in service.

Rapid progress was made on the manufacture of equipment for the Paris-Orleans Railways in France. The 120-ton, 1500-volt high speed passenger locomotive, Fig. 7, was completed and tested and gave every indication of exceeding without difficulty all of the requirements for which it was designed. Speeds of more than 81 miles an hour, for which this locomotive was guaranteed, were easily made, and its riding qualities at high speeds surpass those of any electric locomotive ever built. During final runs a sustained speed of 105 m.p.h. was recorded. Work was also being completed on the construction of a large number of motors and control equipments for multiple unit service on this road, and 40 motors were provided for use on the freight locomotives, which are being built in France.

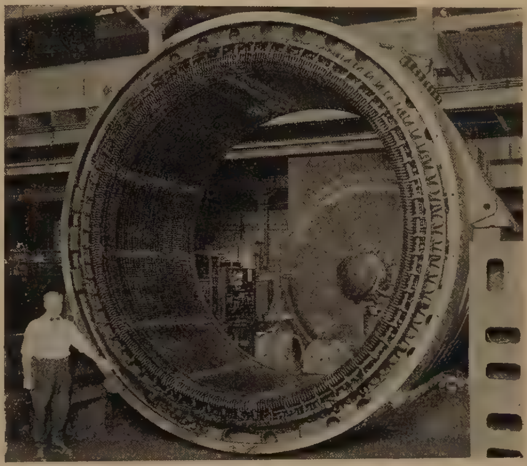


Fig. 5. Stator of 22,750-h.p. Motor for Airplane Carrier Propulsion

An event of considerable interest and importance to engineers connected with heavy steam road electrification was a series of tests of high speed current collection during which a public demonstration of a new type of overhead was made. The outstanding characteristics were the ability of this overhead to collect without sparking as high as 4000 to 5000 amperes on a single pantograph at speeds of from 50 to 60 miles per hour with a normal pressure of pantograph against the trolley wire of 30 to 35 lb.*

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* See G. E. REVIEW, Sept., 1923.

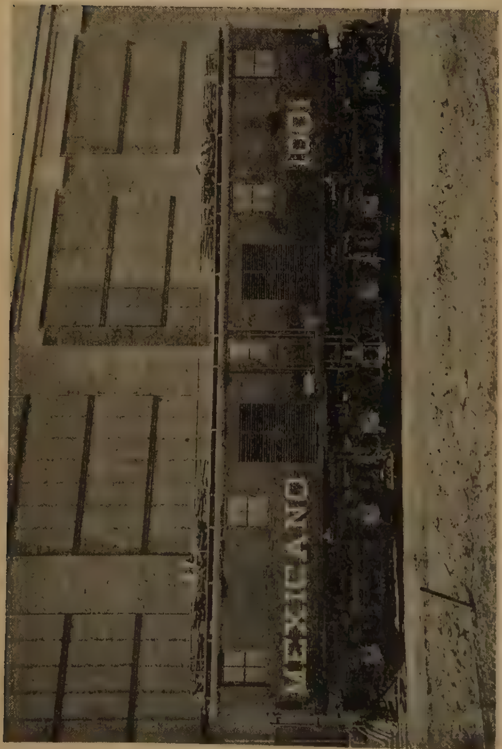

Fig. 6. The First 150-ton Locomotive Completed for the Mexican Railway Co.

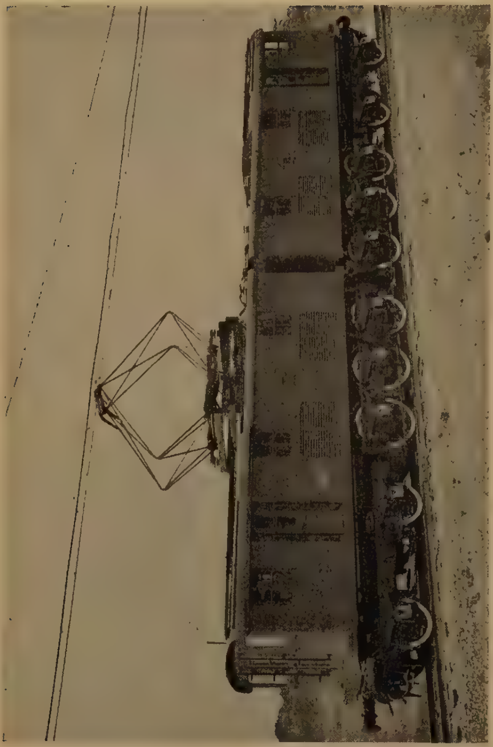

Fig. 7. 120-ton Passenger Locomotive for the Paris-Orleans Railway

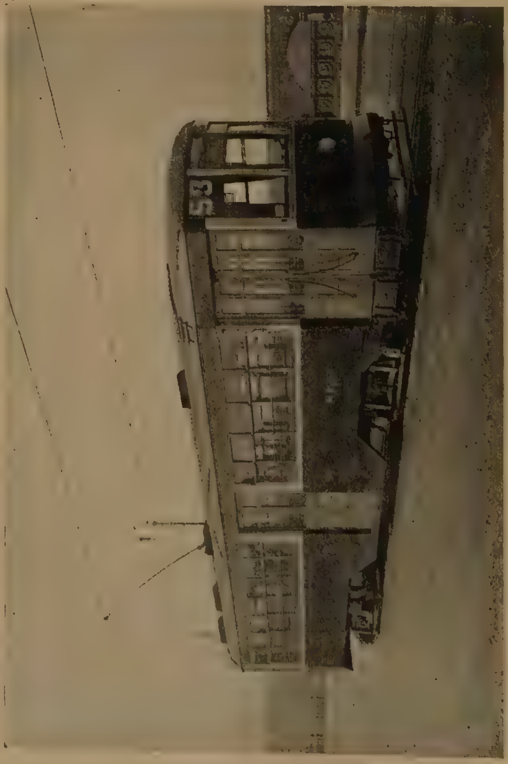

Fig. 8. Recent Type of Two-motor Street Car in Philadelphia

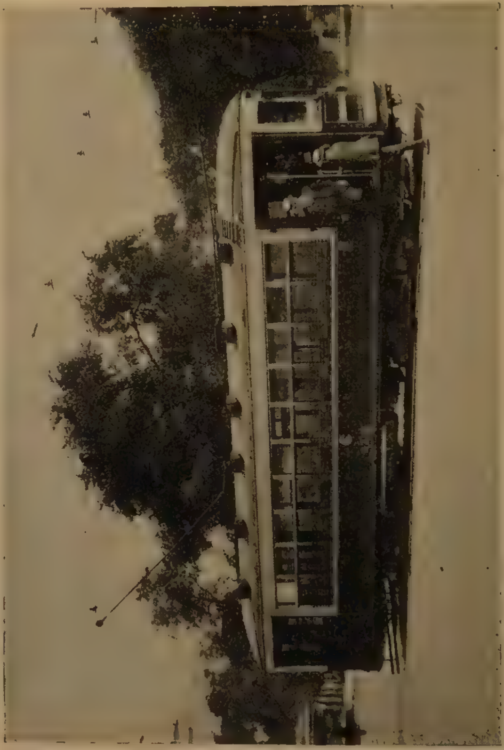

Fig. 9. Two-motor Safety-type Car on Chicago Surface Lines

In order to record accurately and simultaneously the vertical and transverse thrust or impact of locomotive wheels on rails, an interesting device, Fig. 10, called the Otheograph was developed. Numerous tests under a variety of conditions have already been made with both steam and electric locomotives.

This instrument shows by graphic records the effect of each separate wheel of a locomotive or car on each of the two rails. These otheograph ties may be installed in place of the regular ties, either singly or several grouped together on curves or tangent track. Provision is made for two different springs for recording the vertical load. The deflection of the spring is recorded through a lever having a ratio of 8 to 1, the record being traced on paper wrapped around a revolving cylinder similar to an engine indicator.

The operating mechanism provides for moving the recording cylinders simultaneously so that as many records may be taken of each wheel, on each side of the locomotive, as the number of ties that are grouped together.

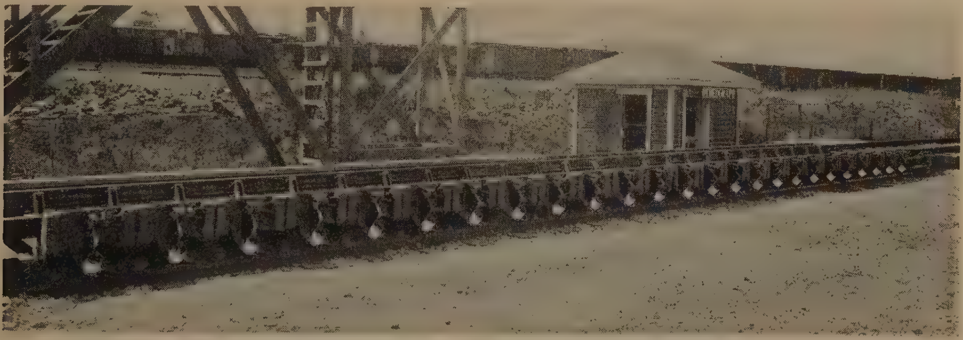

Fig. 10. Twenty-five Otheographs Installed Under Railroad Tracks for Wheel Impact Testing

Light Weight Double Truck Cars

The most effective aid to the rehabilitation of the electric railway system of the country was the remarkable progress in light weight car design. Assistance was also obtained in many cases by the use of automatic railway substations. During the year the light weight car idea spread rapidly from the initial or standard safety car type to double truck cars for various kinds of service.

Some of these light weight installations such as the Cincinnati, Lawrenceburg & Aurora Street Railway, the Kentucky Traction and Terminal Company and others have been in service for a sufficient length of time to secure authentic operating data, which are most convincing. On the Cincinnati, Lawrenceburg & Aurora, for instance, savings over a period of 5½ years aggregated more than $220,000. The Kentucky Traction & Terminal Company is a somewhat more extensive system but has been in service a shorter period. Operating data indicate, however, that the saving per car mile on this road will be even greater than on the Cincinnati line.

The most important group of electric railway equipment completed consisted of 1040 60-h.p. motors, control and air brakes for 520 two-motor cars, Fig. 8, on the lines of the Philadelphia Rapid Transit Company. Another group of 400 motors for the same class of service on the Chicago Surface Lines will, when completed, make a total of 766 of these motors, Fig. 9, for operation in Chicago. There were also completed or under construction 2600 35-h.p. railway motors, including 1000 for Detroit, 600 for Providence, and 400 for Brooklyn.

Under certain conditions the trackless trolley bus appears to be the best solution for local transportation problems. Five of these buses were placed in service by the New York State Railways at Rochester and nine equipments were under construction for the Philadelphia Rapid Transit Company to augment trolley service on city lines.

About 1000 electrically operated turnstiles and fare boxes are now in operation on the Interborough Rapid Transit and the New York Ferry lines.

Automatic Railway Substations

The automatic railway substation continued to be popular with electric railways, both in this country and abroad, as was evidenced by a growing tendency to make electric railway

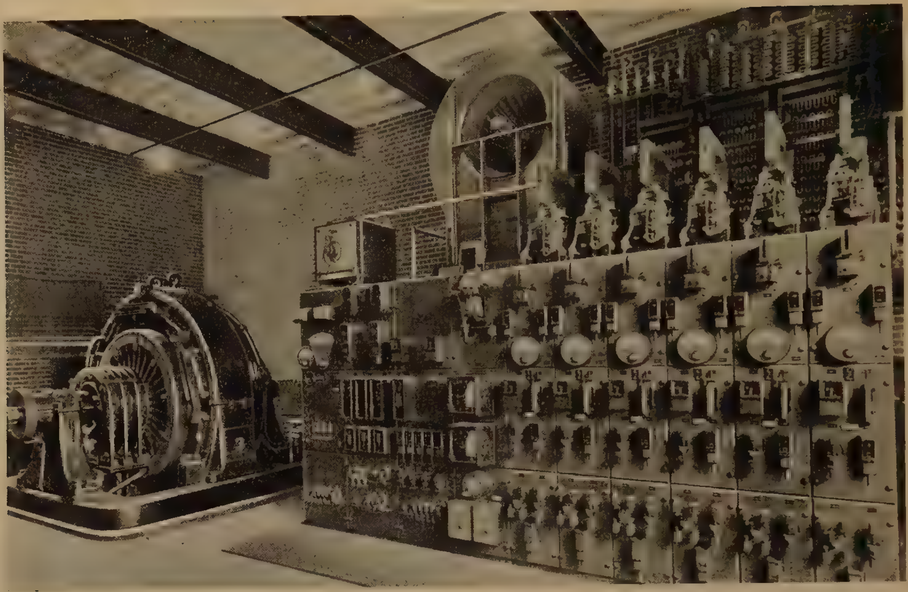

Fig. 11. Automatic Control and Reclosing Feeder Panels with High-speed Circuit Breakers, United Railways Co., St. Louis, Mo.

systems completely automatic by installing automatic control for all substation units. This practice was started a number of years ago by the Des Moines City Railway and the Interurban Railway of Des Moines, and was followed by the re-equipment of the Chicago, North Shore & Milwaukee lines. Some of the more recent examples are as follows:

The Oregon Electric Railway, which operates a heavy 1200-volt interurban line fed from seven automatic substations.

The United Railways of St. Louis, which equipped five substations, Fig. 11, aggregating 7000 kw.

The Detroit Edison Company and the Consumers Power Company with equip-

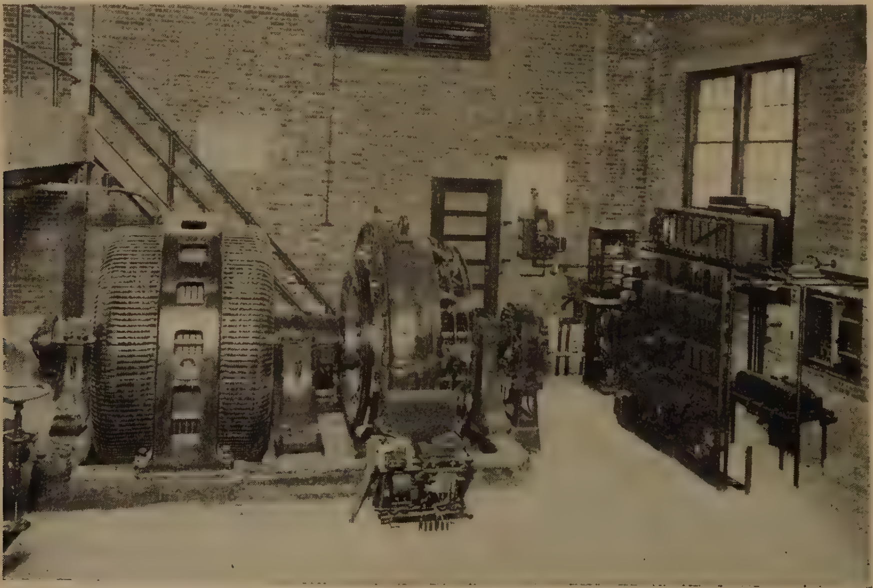

Fig. 12. 2000-kw. Motor-Generator Automatic Substation of New York Central Railroad

ment under construction for a total of thirteen substations aggregating 12,500 kw. in capacity for supplying power to the interurban lines of the Detroit United Railways.

The Public Service Railway Company of New Jersey will shortly place in service five substations aggregating 6500 kw. Included in this undertaking is a two-unit 3000-kw. substation and a portable unit.

On the Pacific Coast the Pacific Electric Railway installed six stations totalling 6750 kw. and the Los Angeles Railway Company also adopted automatic stations for feeding the city lines.

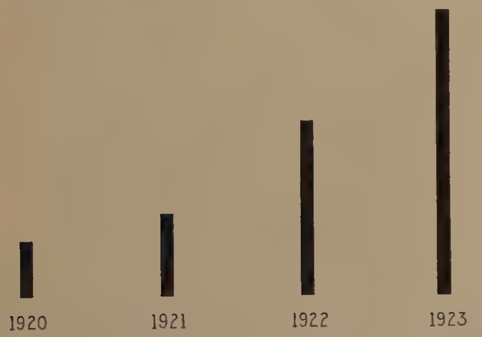

Fig. 13. Relative Annual Capacities of Automatic Switching Equipment

An interesting feature in connection with the last named installation is the use of noiseless building construction for substations located in residential districts. The first station of this type was installed by the Los Angeles Railway Company two years ago, and its success was so pronounced that three stations of similar type have since been placed in service. In addition to the noiseless feature these stations have been made attractive architecturally, and care has been taken to suit the appearance of both buildings and grounds to the character of the district in which they are located.

Some new developments in automatic substation control were necessary to fulfill the requirements of the Moroccan Railways. The electrification of these lines includes three two-unit automatic control equipments. Each of these units will be a 1000-kw. synchronous motor-generator set delivering 3000 volts direct current to the trolley. While some modifications will, of course, be necessary to control 3000-volt units, no difficulties are anticipated in adapting the standard equipment to this service. This is the second steam road electrification to employ 3000 volts direct current with automatic substations; the first being the South African Railways.

Automatic reclosing feeder equipments using the high speed type of circuit breaker were provided for the United Railways of St. Louis, Detroit United Railways, Denver Tramways Company, the Public Service Railway Company of New Jersey and other roads. To date a total of 100 reclosing feeder equipments have been built.

In the steam railroad field the automatic substation equipment under construction included a second unit of 2000 kw. capacity which will be installed at the 110th Street substation of the New York Central Railroad Company. Incidentally, when this station, Fig. 12, is in operation, it will have a total capacity of 4000 kw. and will be one of the largest automatically controlled railroad substations in service.

Another important steam road which started up automatic equipment during the year was the Victorian Railways, which utilized automatic control for substations feeding the Melbourne Suburban lines. There are five of these stations, three being equipped with two 1000-kw., 1500-volt units and the other two with one 1000-kw. unit each.

At the close of the year there were 70 railroad companies using G-E automatic substations with 235 equipments aggregating more than 170,000 kw. in capacity either in service or under construction. Thirteen railway companies each operate automatic substations with capacities of 4000 kw. or above.

AUTOMATIC STATIONS

There were many indications that the automatic station had become an accepted factor in the electrical industry as actual installations were more numerous than in preceding years, Fig. 13, and many of the equipments built were of record capacity. Installations were also made in foreign countries for the first time.

It was natural that automatic switching equipment should undergo many modifications in the early period of its application, but very few radical changes in design were made during 1923. Minor improvements were made but the automatic station is apparently fast reaching the stage of mass production and standardization of design.

Much attention was given to the perfection of wiring diagrams, instruction books, the arrangement of the devices and the wiring that compose the automatic switching equipment, in order to facilitate installation and maintenance. A typical automatic switching equipment for a waterwheel-driven generator, Fig. 14, indicates the symmetrical arrangement of the devices now secured and the provision of numbered plates near each device. The back view of the panel, Fig. 15, shows the grouping of wires, a number plate near each device and the terminal board at the bottom with each terminal numbered on the copper bar above. The construction wiring diagram furnished with each equipment contains these corresponding terminal numbers and shows how each terminal should be connected to other numbered terminals on the various pieces of apparatus remote from the panel.

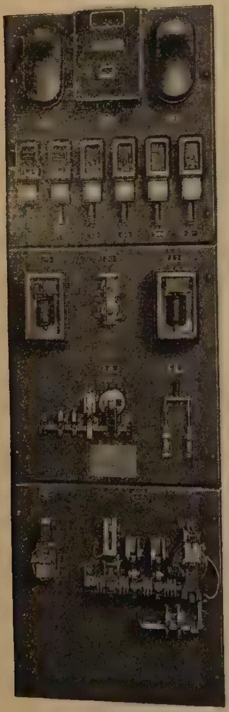

Fig. 14. Automatic Control Panel showing Arrangement of Apparatus and Number Plates

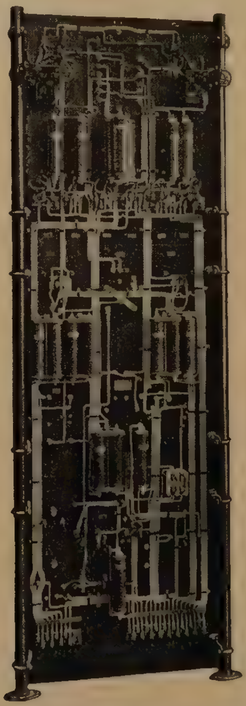

Fig. 15. Back View of Automatic Control Panel showing the Grouping of Wires

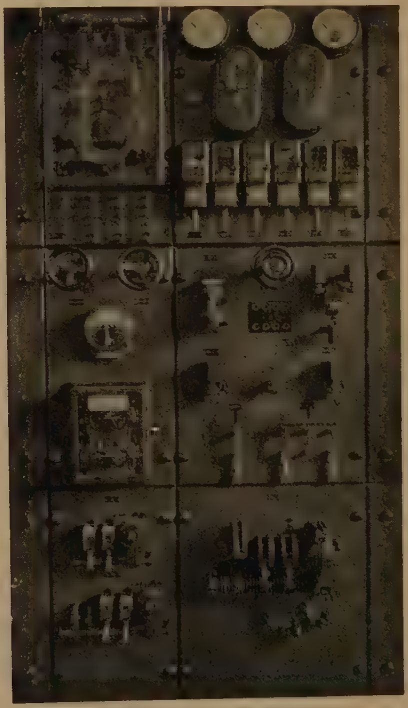

Fig. 16. Instrument and Relay Equipment for 900-kv-a. Waterwheel-driven Generator

The development of water power sources received more attention than ever before because of the high cost of fuel and labor and the need of additional sources of power to meet the needs of electrical expansion. Before the advent of the automatic station it was usually uneconomical to develop the water power sites of small capacity because of operating costs, but these small sites are coming rapidly into prominence, and automatic hydro-electric stations are now operating or being installed in nearly every state in the Union.

The largest single unit automatic hydro-electric station in the world is being installed by the Adirondack Power and Light Corporation for their Sprite Creek Development near Little Falls, N. Y. It is rated 7500 kv-a., 6000-volt, 3-phase, 60-cycle, the largest previous equipment of this type being of 5000 kv-a. capacity.

An interesting automatic hydro-electric equipment of 900 kv-a. was provided for the Wairarapa Electric Power Board, Fig. 16, at Kourarau, New Zealand. This station will be under the complete control of the operator in the main station several miles away, who will be able to start and stop the station, regulate the load at will and receive indications showing the positions of the main control elements in the automatic station. This is accomplished by means of selector supervisory remote control apparatus, with only three control wires between the stations.

The Kyushu Electric Light and Traction Company in Japan is now operating a 1300-kv-a. automatic hydro-electric station which was the first to be installed in Japan.

The use of automatic substations in mining service was very decidedly increased and has fulfilled a real need in this particular field, where trained operators are scarce, many comparatively small installations are required to meet operating conditions, and where the power output must be reliable.

The automatic switching equipment for controlling synchronous motor-generator sets for this class of service is very simple and in most cases automatic direct-current reclosing feeders form a part of the installations. Because of the nature of mining work and conditions surrounding the electrical equipment where short circuits and heavy overloads may occur frequently, the automatic direct-current reclosing feeder is always in readiness to take care of such abnormal conditions. It opens the feeder when trouble occurs and will not reclose it until the trouble has disappeared.

The Retsof Mining Company, Retsof, N. Y. installed one of these substations in a salt mine 1100 ft. underground, the various devices being given a special treatment to prevent rusting under these severe service conditions. This 300-kv-a. station, Fig. 17, is started when the 2300-volt, 60-cycle line is energized from a partially automatic underground station in conjunction with which it operates.

Many mining companies now use automatic direct-current reclosing feeders even in their manual substations, and feeder equipment has been standardized for this service. Automatic switching equipment for synchronous converters for mining service is also being used extensively.

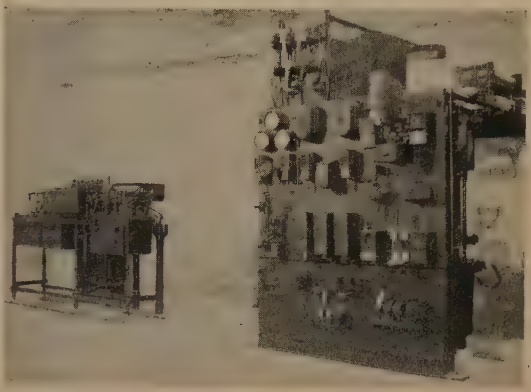

Fig. 17. 300-kv-a., 2300-volt Automatic Equipment Installed Underground in a Salt Mine

Both direct-current and alternating-current feeder equipments are now highly standardized and furnished with a counter attached to the line contactor which records the operations of the contactor and thus tells how many times the feeder equipment has been called upon to function.

Some of the most interesting installations made were in the lighting field. By means of a

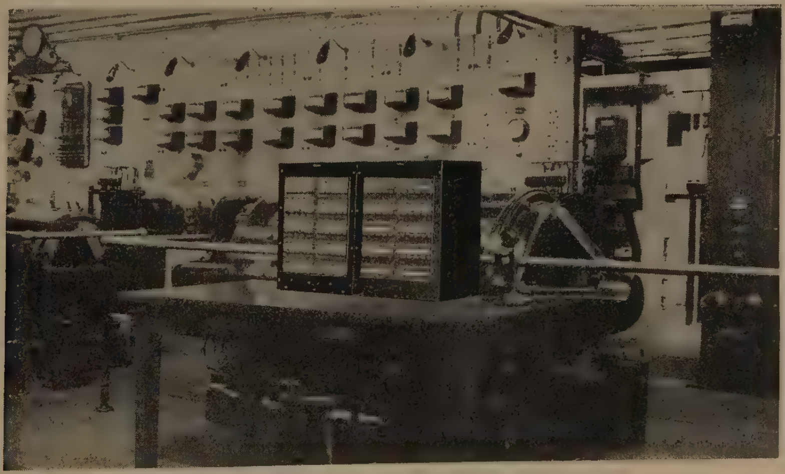

Fig. 18. Distributor Supervisory Equipment for Controlling Alternating-current Feeders

combination of devices especially designed to regulate the voltage for varying load, the requirements in this class of service were met very satisfactorily.

Two fully automatic motor-generator sets of 1875 kw. each were completed for the Rochester Gas and Electric Company for supplying energy to a nearby and a distant distribution center, a notable feature of the equipment being the method adopted for maintaining the voltage at these two points. A balancer set rated at 275/137.5 volts, 1260 amp. for maintaining balanced current conditions on the three-wire system constitutes part of the equipment in this station and requires manual starting but thereafter automatically maintains the desired balanced condition.

The increase in automatic substation installations created a corresponding demand for centralized supervision, Fig. 18, in large power systems and two main classes of equipment were standardized for this service. The first class is called the selector type and is suitable for installations in which few operations are required per station and where the stations cover a wide area. The second class is called the distributor type and is best suited for power systems where a large number of operations per station are required and the stations are within a radius of twenty miles.

WATERWHEEL GENERATORS

The first of the two 65,000-kv-a., 12,000-volt, 25-cycle, 107-r.p.m. waterwheel generators for the Niagara Falls Power Company was completed and shipped in sections to the power site for assembly. It is the largest machine of its type, Fig. 19, both in capacity and physical dimensions, so far constructed.

For foreign shipment there were under construction two 30,000-kv-a., 11,000-volt, 300-r.p.m. units for the Nippon Electric Light and Power Company of Japan, which exceed in capacity any previously built for that country.

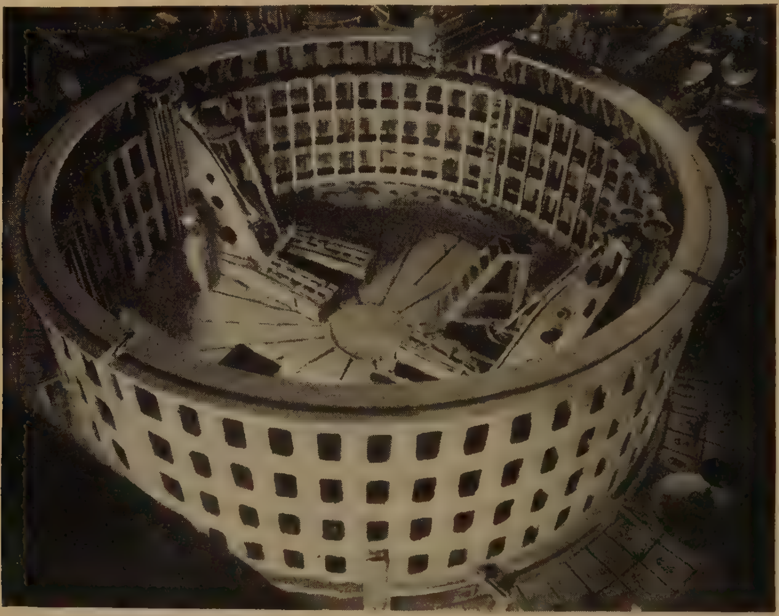

Fig. 19. Stator Castings of 65,000-kv-a. Waterwheel Generator Arranged on Turntable for Machine Work

Another 30,000-kv-a., 11,000-volt machine for the Portland Railway Light and Power Company of Oregon was designed for operation at 514 r.p.m., thereby carrying the operating speed for a generator of this capacity well beyond previous practice.

An unusual thrust bearing construction was provided for two 8200-kv-a., 150-r.p.m., and two 15,000-kv-a., 120-r.p.m., 6600-volt generators for the Phoenix Utility Company for installation in Alexander, Idaho, and Fond du Lac, Minnesota. The upper bearing bracket which is ordinarily used to hold the suspension thrust bearing was omitted altogether in these machines and the bearing was located in the lower bracket between the rotor and the waterwheel, the lower bracket being strengthened for the exceptional service required of it.

This arrangement permits ready access to the stator coils for inspection or replacement as the rotors of the smaller machines or the stators of the larger ones can be lifted with an overhead crane by the removal of a few bolts.

A striking indication of the high efficiencies attained in modern machine construction is found in five 5000-kv., 300-r.p.m., 650-volt, horizontal shaft, direct-current waterwheel generator sets, consisting of two 2500-kw. units mounted on a common base and operated in parallel, which were built to meet a guaranteed efficiency of 94.8 per cent based on input-output determination losses.

The acceptance tests on one of these units, which was selected as representative, showed that even this high guarantee was exceeded by a substantial margin.

FREQUENCY CONVERTERS

A frequency converter of exceptional capacity and unusual characteristics was constructed for tying together the 25 and 60-cycle systems of the United Electric Light & Power and the New York Edison Companies. The set, Fig. 20, consists of the following units:

(1) A 37,000-kv-a. wound rotor induction motor having a 60-cycle stator and 25-cycle rotor.
(2) A 25-cycle, 25,000-kv-a. synchronous a-c. generator.

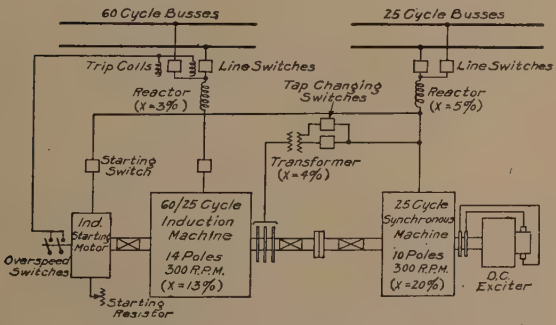

Fig. 20. Simplified Diagram of Connections for an Induction-synchronous Frequency-converter Set

(3) A 115-kw. direct connected exciter for exciting the synchronous generator.
(4) A 1600-h.p., 25-cycle induction starting motor.
(5) A 17,100-kv-a. air blast transformer connecting between the slip-rings of the induction machine and the high voltage 25-cycle bus.

The synchronous machine is a 10-pole generator having a synchronous speed of 300 r.p.m. The 60/25-cycle induction unit is wound for 14 poles. At 60 cycles, it would have a synchronous speed of 514 r.p.m. but by holding the rotor speed down to 300 r.p.m. with the synchronous generator, a slip of 214 r.p.m. is obtained in the induction machine, which gives 25 cycles at the collector rings of the rotor. The transformer between the induction unit and the 25-cycle bus makes it possible to use a low voltage collector on the induction unit and also gives an opportunity for ratio adjustment for control of power-factor on the induction machine.

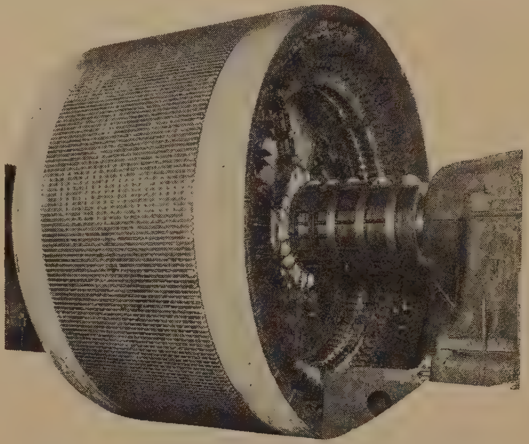

Fig. 21. Rotor of 37,000-kv-a. Induction Unit of Frequency-converter Set

The induction type unit, the rotor of which is shown in Fig. 21, furnishes an electromagnetic tie between the 25- and 60-cycle systems, similar to a transformer tie between two parts of a system of one frequency. In other words, this machine forms a voltage tie between systems in addition to being a power and frequency tie; and any variation or disturbance of voltage on one system will be transmitted to the other through this tie in a manner similar to that obtained through a transformer. The effectiveness of this voltage tie is dependent upon the reactance of the circuit through the induction machine between the two systems. It is also dependent upon the ratio of frequency of the two systems.

This unit will supply 150,000 kv-a. to the 60-cycle system with a short circuit on the 60-cycle bus and with 25-cycle bus voltage maintained. In the reverse direction, it will supply 191,000 kv-a. to the 25-cycle system with 60-cycle bus voltage maintained. The induction unit will be excited from the 25-

cycle synchronous generator and the set is designed for unity power-factor input and output in either direction at full load.

The kw. capacity of the set is nearly three times that of the largest frequency converter previously built, and marks a new epoch in the construction of horizontal shaft alternating-current machines. The induction unit is the largest induction motor in the world and has a continuous rating of 37,000 kv-a. The synchronous generator rated 25,000 kv-a. is larger than any horizontal shaft salient pole generator previously constructed and the installation also includes the largest air blast transformer in the world, rated 17,100 kv-a.

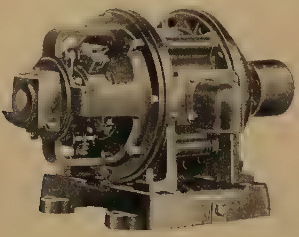

Fig. 22. Squirrel-cage Induction Type of Single-phase Motor

The set has an over-all length of 49 ft. 4 in. and is 22 ft. 10 in. wide, the total weight being 430 tons and the weight of the transformer 39 tons.

INDUSTRIAL MOTORS

The single-phase motor is an important factor in many industrial applications, but early designs had certain electrical and mechanical characteristics which tended to limit the field of its practical utility. A new type, Fig. 22, which operates on the squirrel cage induction principle entirely eliminates the short circuiting switches heretofore considered essential, and permits the simplest possible construction.

It combines high starting torque with low current demand and has operating characteristics similar to those of the induction motor. Both the maximum and accelerating torques are approximately 200 per cent of full load torque without any low points during acceleration. The no load and full load speeds are respectively about 3 per cent above and below synchronous speed, giving unusually close regulation for a motor of this type.

The stator winding consists of simple concentric polar windings arranged for double voltage connections. The rotor contains the cast squirrel cage winding and a repulsion wire winding of the multiple type with equalized commutator connections to insure uniform distribution of armature currents.

A complete new line of 40 deg. continuous duty, riveted frame, polyphase motors, in sizes up to 15 h.p. was designed with numerous improved electrical and mechanical characteristics as compared with previous construction for this class of motor.

The electrical improvements comprise reduced heating, higher efficiency and higher power-factor at full and fractional loads, and increased starting torque, the maximum torque ranging from 275 per cent to 300 per cent of full load synchronous torque for different sizes. The accelerating torque curves are much freer from dips than those of preceding types.

The principal mechanical changes include from 50 per cent to 100 per cent increase in oil reservoir capacity, a new method of directing the ventilating air so as to prevent dirt from settling on the windings, and a "cast" rotor which is a one-piece structure without joints or high resistance spots, Fig. 23.

As more than a million of the preceding type of motor are in service today the cumulative economic value of the detailed improvements embodied in the new design will be effective in a great variety of industrial motor applications.

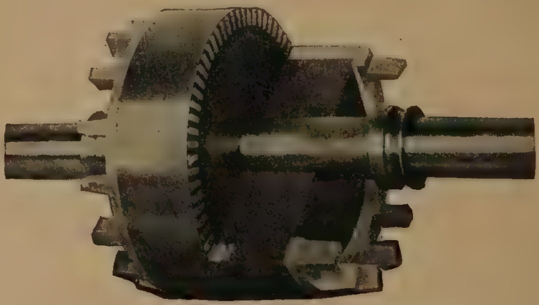

Fig. 23. Construction Details of "Cast" Rotor for Polyphase Motor

In order to meet the demand for an alternating-current adjustable-speed motor for applications where a shunt speed characteristic is either necessary or desirable, a new type of brush shifting motor, Fig. 24, was developed for three-phase and two-phase circuits, in sizes up to 75 h.p. for 550 volts and below.

The primary and secondary windings of this motor are similar to those of a standard slip ring induction motor except that the primary winding is placed on the rotor and the supply lines are connected to the slip rings. In the same rotor slots there is provided a second winding known as a regulating winding which is constructed like a direct-current armature winding and connected to a commutator. The stator is provided with a phase wound secondary winding and each phase is brought out separately, one end of the phase to one brush yoke and the other end of the phase to another brush yoke. These brush yokes are mounted one at each end of the commutator and are shifted by a handwheel mechanism so constructed as to move the brush yokes in opposite directions.

The secondary winding is so connected that the circuit through each phase is completed by means of the commutator. When the brushes of both yokes are in line on the same commutator bars the secondary phases are short circuited and the motor operates as an induction motor. As the regulating winding is placed in the same slots as the primary winding, an alternating voltage of constant value is induced in the regulating winding by the primary flux. As the brushes are moved apart, a section of the regulating winding is included in series with the secondary winding, thereby injecting into the secondary circuit a voltage which, by proper design, has the effect of changing the speed of the motor.

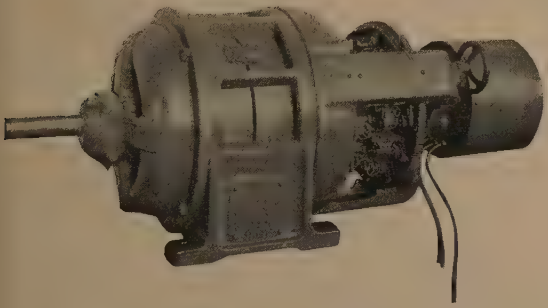

Fig. 24. Adjustable-speed, Brush-shifting Motor showing Handwheel for Moving Brushes

The electrical circuits of the motor are simple and are nothing more or less than those of a slip ring induction motor with a few turns of a regulating winding in series with the secondary. The operation is likewise comparable with that of an induction motor, the speed regulation being similar to that of an induction motor with a somewhat increased value of slip.

During the year considerable work was done towards standardizing the bores of small high speed motors used generally by the woodworking trade. Through the efforts of several of the electrical companies, most of the tool manufacturers are now using a definite bore for these shaftless motors. Before this standardization, there were a great many different bore dimensions for the same frame which was decidedly objectionable from a manufacturing standpoint.

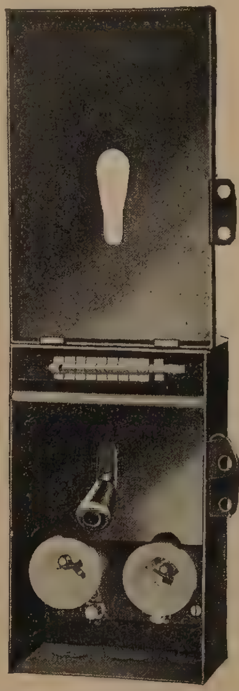

Fig. 25. Starting Switch with Cover Open showing Arrangement of Locking Plate

INDUSTRIAL MOTOR CONTROL

A number of improvements were made in the apparatus designed for the control of industrial motors, which, despite the relatively small size of the individual controller, are of great economic value due to the vast extent of the field of present day industrial motor application.

Among the more important of the new designs is a starting switch for three-phase motors, Fig. 25, for sizes up to 7½ h.p., 440 and 550 volts, which is of the positive quick-make and quick-break tumbler type. This switch is totally enclosed with the operating handle on the front and a locking plate on the side, so that it may be locked to prevent either the opening of the box, the closing of the switch, or both. An interlock between the handle and the cover makes it necessary to have the switch in the open position before the cover can be opened.

A new form of thermal cutout is used with this switch which eliminates the objectionable features possessed by the protective plug or left-handed screw shell, and possible breakage of the shell when the switch is subjected to vibration. The complete device is more compact than any previously produced for this service.

The wattmeter jack type disconnecting switch, Fig. 26, was designed primarily for mounting on top of starting compensators, but is also suitable for mounting independently. It is arranged so that it cannot be operated in either direction while the cover of the box is shut, and the cover can be padlocked shut so as to prevent the throwing of the switch except by a person possessing the key. The device serves as a disconnecting means and its contacts are designed so that an ammeter or wattmeter jack can be inserted to take current or power readings without opening the motor circuit.

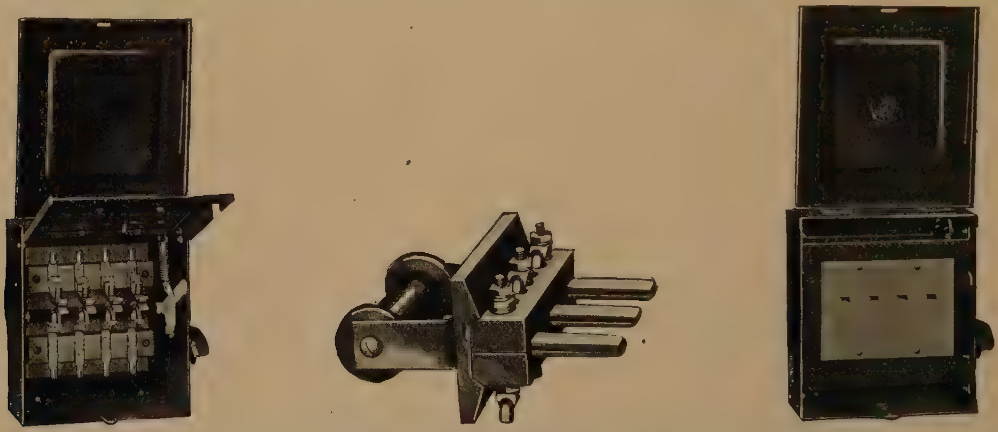

Fig. 26. Jack-type Disconnecting Switch showing Safety Features and Wattmeter Plug

An ingenious design of a magnetic switch provided with a thermal overload relay, Fig. 27, was developed to meet the demand for starters of compact construction and for mounting in the frames of machines. It is suitable for motors up to 10 h.p., 550 volts, 25 to 120 cycles and the units can easily be arranged on panels so as to insure complete control, at any point desired, of machines driven by two or more motors of either the same or different ratings. The motors can be started simultaneously or in sequence by means of magnetic time element relays which are adjustable and automatically determine the accelerating period from point to point.

MOTOR APPLICATIONS

To meet the requirements of the Russian Government in regard to electrical equipment for oil well drilling, two sizes of totally enclosed induction motors, Fig. 28, were developed, rated 75 h.p. and 50 h.p., 750 r.p.m., with a temperature rise of 45 deg. C. These motors are unique in that they are the largest totally enclosed, self-ventilated motors yet manufactured; previous designs in these sizes having employed water as a cooling agent.

There is no circulation of air from external sources through the rotating elements of the motors. A stream of air from the motor fan is directed against the external surface of the enclosing shell with sufficient cooling effect to keep the temperature rise of the motor within safe limits, even with a 25 per cent overload.

These motors, with control equipment, are intended for use in gaseous atmospheres and while "sold without warrantee for a particular use," they are designed to stand the shock of an internal explosion. No attempt was made to have the joints airtight, but the machined flanges are of sufficient width to cool escaping gases below the temperature which would cause an explosion of external gases.

All electrical contacts in the control equipment are oil immersed to minimize the possibility of a spark from this source causing an explosion.

With minor changes in design, this type of otor could be made suitable for many pplications where the totally enclosed features are desirable, but where protection gainst explosive gases is not required.

The H. C. Frick Coke Company is installing belt conveyor approximately five miles ong for transporting coal from the mine vorkings to the shipping station. It consists f twenty sections, each driven by an induction motor. The motors vary in size from 0 to 175 h.p. and are all of the wound rotor ype. Solenoid brakes are provided for topping and holding the conveyor belts vhen power is cut off and the control is so rranged that the motors start in sequence eginning at the delivery end. As each motor eaches full speed, it energizes the starting ircuit of the next succeeding motor. If ny motor stops, it automatically stops all he motors preceding it in the conveyor ystem but allows those following it to run nd clear the belts of coal.

Prior to 1916, steam-driven coal hoists were sed exclusively where extremely high rope peeds were required. The installation in 1916 f the coal tower hoist at the Essex Street tation of the Public Service Electric Company, N. J., marked the entrance of electric rive into the high speed field, a rope speed of 260 ft. per min. being utilized for the 80-ft. lift. Alternating current motors and ontrol were used. During the period between 916 and 1920 there was further development

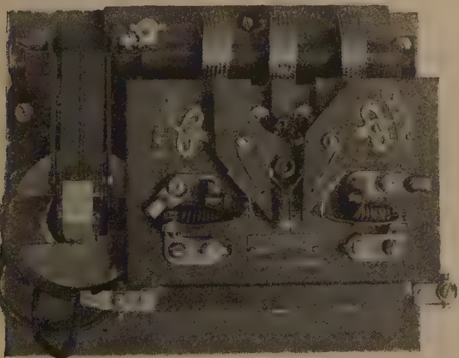

Fig. 27. Magnetic Switch Equipped with a Temperature Relay

f the alternating current high speed coal ower.

Electrical equipment was provided in 1923 r two direct current coal tower hoists for the ew Hudson Avenue Station of the Brooklyn dison Company, to give a hoisting rope speed of 1460 ft. per min. and a lowering rope speed of 1680 ft. per min. on the 200-ft. lift and to give a guaranteed delivery of 250 tons per hour, using a 2.5-ton grab. The hoist motor is rated 625 h.p., is direct connected to the hoisting drums, and takes its power from a 575-kw. motor-generator set mounted in the tower and driven by a 700-h.p., 2300-volt, 3-phase, 60-cycle induction motor.

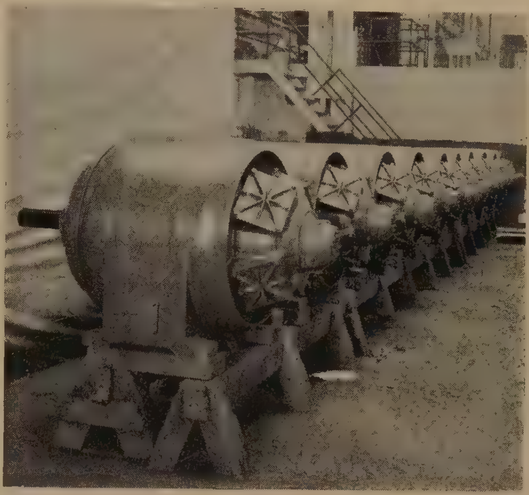

Fig. 28. Totally Enclosed Induction Motors for Oil Well Service

Generator field control is used on the hoist motor and represents the first application of this type of control to high speed coal tower hoists. By this substitution of field control for armature control, a marked advance in efficiency, maintenance, flexibility, and tonnage is confidently expected.

A woodworking machine driven by five motors was provided with a special control equipment consisting of five drum controller mechanisms, Fig. 29, mounted in a single case.

The case also contains an overload relay for each motor and the complete control unit is so interlocked that upon failure of voltage or overload, even though it is on only one spindle, the whole machine will be shut down. It is also necessary that all controllers be in the off position before the under-voltage contactor can be closed, thereby preventing an unexpected start of any motor.

The four main motors are of the Y-delta "start-run" type and the controllers provide a reverse Y connection for plugging the spindle motors to rest. The feed motor is of the four-speed multi-speed type and the controller provides the necessary connections to obtain these speeds.

A noteworthy installation of motor drives and control was made at the plant of the *Public Ledger*, Philadelphia, Pa., for operating a battery of new printing presses. This equipment in size, arrangement and construction details is unusual and represents a distinct advance over previous practice. An improved form of control is employed, embodying the new bent frame contactors and relays which were designed especially for this service together with a simplified and improved form of pilot motor operating mechanism.

The printing presses are arranged in three rows, each row 147 ft. long and comprising twelve 16-page units. These twelve units in each row can be combined as four sextuples, three octuples or two decuples and one quad. On each row there are four double-motor drives; two of 60 h.p. and two of 100 h.p. capacity.

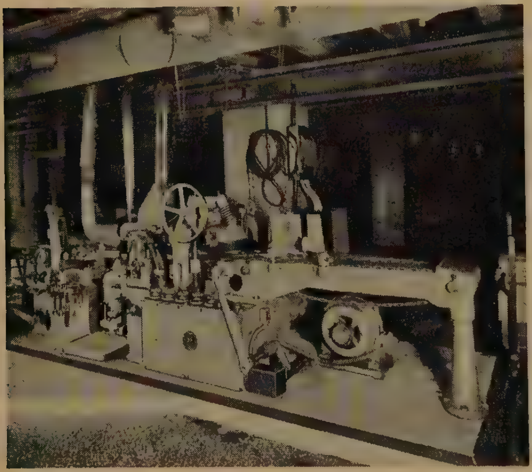

Fig. 29. **Wood Moulding Machine Driven by Five Motors Having Special Control**

To effect the proper combination of push button stations on the different units with the drives and controls selected to operate the different combinations, there was installed an improved selective control arrangement to indicate when the desired combinations are obtained.

All of the old mechanical equipment of the Philadelphia *Ledger* is being discarded and it is expected in the new plant greatly to increase the speed of production of newspapers, to decrease the labor involved, and to improve the working conditions.

This plant includes, as well as the 36 units for printing the morning and evening editions, a 20-cylinder color press for portions of the Sunday supplement, which can be operated as two separate presses, each with its own drive, or as a single press with the two drives functioning in parallel.

STEEL MILLS

Of the present total of over 612,000 h.p. of G-E main roll steel mill drives, over 44,000 h.p. (normal continuous rating) was added during 1913. These totals neglect all motors under 300 h.p. The tendency towards the use of high speed motors with reduction gears which has been quite marked for the last few years continued to gain headway and over 90 per cent of the new motors were for geared drive.

Two 5750-h.p., 94-r.p.m., 6600-volt, 25-cycle motors were installed at the Woodlawn Plant of the Jones and Laughlin Steel Corporation to drive 18-in. and 21-in. billet mills. These replaced a steam engine and were in addition to two motors of the same rating previously installed.

Three two-speed pole-changing induction motors were constructed. One was a 500/250-h.p., 750/375-r.p.m., 3000-volt, 50-cycle machine for a 10-in. merchant mill of the Consolidated Rolling Mills Company of Mexico City; the installation also including a 300-h.p. single-speed motor for a 16-in. rougher. These motors replaced a steam engine. Two 800/800-h.p., 900/720-r.p.m., 2220-volt, 60-cycle motors were built for the Knoxville Iron Company for merchant mill drive.

During the year three machines were constructed, each being the largest of its type ever built in America. The first was a 4500/4500-h.p., 500/300-r.p.m., 25-cycle, 2200-volt Kraemer equipment for driving the 14-in. merchant mill of the Inland Steel Company. The other two, built for the Ford Motor Company, were an 8000-h.p., 240-r.p.m., 13,200-volt, 60-cycle constant speed induction motor for driving an interrupted-continuous blooming mill, and a 4500/4500-h.p., 110/67.5-r.p.m., 500-volt direct-current motor for driving a 14-in. merchant mill. The 8000-h.p. motor, which is notable also on account of its high voltage, has the largest continuous horse power rating of any industrial motor, while the 4500-h.p. motor has the largest continuous horse power rating of any single unit, direct-current motor, built in this country.

The steel industry on the Pacific coast is being rapidly developed as is evidenced by the following installations. The Columbia Steel Company of Pittsburg, California, utilized a 1500-h.p., 360-r.p.m., 2200-volt, 60-cycle motor for driving a sheet mill and also an 1800-h.p., 514-r.p.m. motor for a rod mill drive. The Metal and Thermit Corporation of South San Francisco, California, installed a 1500-h.p., 360-r.p.m., 4000-volt, 60-cycle motor to drive their sheet mill.

A 2500-h.p., 150-r.p.m., 6600-volt, 25-cycle induction motor was installed on the 28-in. billet mill at the Midland Plant of the Pittsburgh Crucible Steel Company; replacing a 1600-h.p. motor, utilized during the war, to give increased production.

One of the most important developments of the year was the building of alternating-current brush-shifting motors with shunt characteristics. Two machines of this type, which gives adjustable-speed without auxiliary apparatus, were under construction for the Halcomb Steel Company, Syracuse, New York, for driving merchant mills, and are rated 600/400/200 h.p., 321/214/107 r.p.m., 440 volts, 25 cycles and 500/385/250 h.p., 130/100/65 r.p.m. for the same power supply. There has long existed a need for an adjustable-speed alternating-current motor that was simple and did not require a large amount of auxiliary equipment, and whose speed would be practically independent of its load. This machine is the first practical piece of apparatus to meet these requirements.

The revolving frame or super-synchronous motor which has proved so successful in cement mills and other applications well suited to synchronous motor drive, except for starting conditions too severe to allow the use of the standard type of this machine, was applied to rolling mills. Two of these motors rated 580 kv-a., 0.7 p.f. (500 h.p.), 360 r.p.m., 440 volts, 60 cycles were being built for the Rome Brass and Copper Company.

The new 20-in. hot strip mill of the Otis Steel Company was placed in operation. The roughing end of the mill is driven by an 1800-h.p., 500-r.p.m., 6660-volt, 25-cycle induction motor, the next three stands are each driven by a 1500-h.p., 280/420-r.p.m., 600-volt direct-current motor and the three finishing stands by three 1800-h.p., 600-volt, direct-current motors of 115/173 r.p.m., 143/201 r.p.m., and 153/230 r.p.m. respectively. Direct-current power is obtained from three 1500-kw. synchronous converters.

A reversing blooming mill drive rated 6500 h.p. continuous at 50 r.p.m., and 17,000 h.p. maximum at 45 r.p.m., capable of a maximum speed of 120 r.p.m. was completed for the Otis Steel Company.

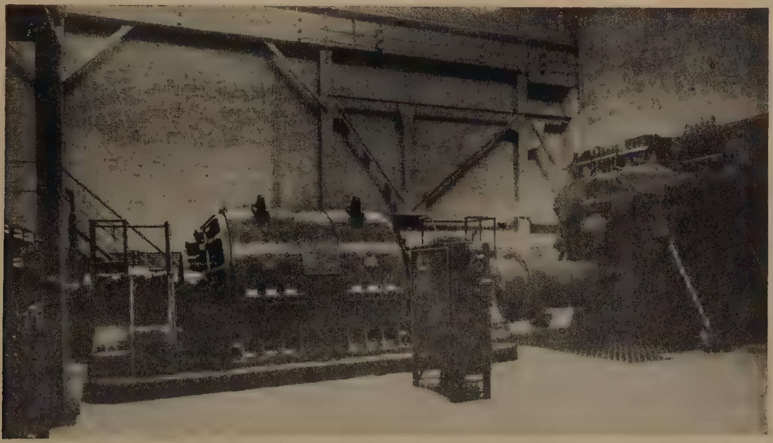

Fig. 30. Double-unit Reversing Direct-current Motor Driving 30-in. Skelp Mill

Reversing drive, Fig. 30, was supplied for the 30-in. Universal skelp mill of the Youngstown Sheet and Tube Company. This drive, which replaced a twin simple reversing steam engine, is rated 4000 h.p. continuous at 75 r.p.m. and is capable of a top speed of 135 r.p.m. Current is supplied by means of a flywheel motor-generator set, Fig. 31, consisting of a 2500-h.p., 6000-volt induction motor driving two 1800-kw., 650-volt direct-current generators.

A small reversing drive for a hot copper mill was placed in regular production. This is rated 350 h.p. continuous at 270 r.p.m. and 1000 h.p. maximum and is capable of a maximum speed of 470 r.p.m. It is the fourth reversing drive applied to hot copper mills and the results have amply justified the higher initial cost involved.

There was also great activity in cold strip mill drives and in addition to many single stand installations, several large tandem equipments were installed.

ELECTRIC WELDING

The most important achievement in arc welding was a radical improvement in the construction of the electrode. As the result of exhaustive research and experiment, a mechanical construction was developed, which makes it easy to combine the desired welding flux within the body of the electrode, thus securing all of the advantages which could be obtained with an externally coated electrode, without its disadvantages.

This composite construction, Fig. 32, adapts itself for any desired application. The flux selected for the particular case is enclosed in the annular space between the core and the sheath, its amount being controlled by the thickness of this annular space.

Some of the advantages secured by incorporating the flux within the body of the electrode, rather than applying it as a coating or cover on the outside, are as follows:

1. For coated electrodes it is usually necessary to incorporate with the flux, materials, otherwise undesirable, whose function is merely to serve as a binder for holding the flux on the outside of the electrode. Such materials add to the quantity of the slag produced, making it more difficult to avoid inclusions in the deposited metal.
2. When the flux is enclosed, it cannot flake off or dissipate before it actually enters the arc.
3. The sheath, which receives the current and conducts it to the arc, always presents a clean surface to the holder or current feeding device. This is particularly advantageous with the automatic welding machine, where current is led in through the feed rolls or nozzle as the electrode wire travels through in a continuous length.

The results of this research work were made available commercially by the development of new methods of manufacture, the ingredients of the fluxes being fused together in an electric furnace, finely ground and mixed with suitable solvents. Special machines were developed for applying the sheath to the core while feeding in the exact amount of flux required to fill the intervening space. These machines have attachments for straightening and cutting the finished electrodes, where these are to be used for hand welding, while the finished electrode material for use with automatic welding machines is wound on reels in continuous lengths.

There was a more extended use of resistance line welding than in previous years due to the production of new welding machines which gave increased operating speeds. The steel tanks for all the distribution sizes of G-E transformers are now being constructed by this method.

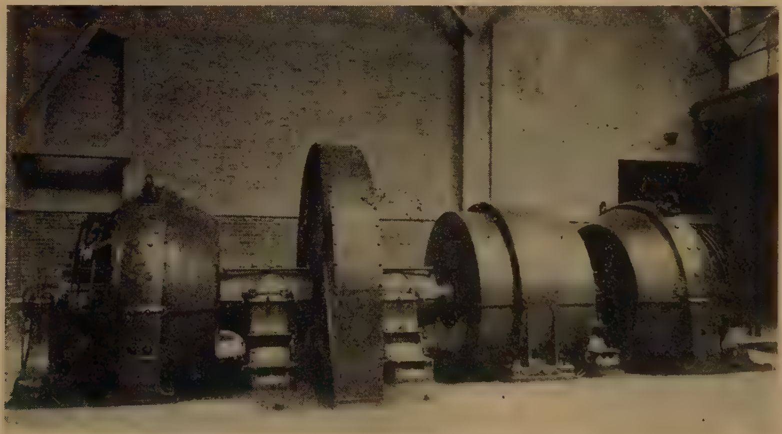

Fig. 31. Flywheel Motor-Generator for Supplying Current to Reversing Skelp Mill Motor Shown in Fig. 30

INDUCTION FURNACES

The new type of induction furnace, which utilizes the force of electro-magnetic repulsion existing between transformer primary and secondary windings, to cause a circulation of molten metal between the heating circuit and the melting pot, was operated only experimentally during 1922.

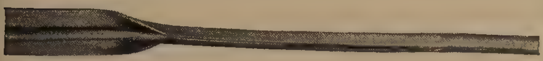

Fig. 32. New Type of Welding Electrode

A, flat strip with wire core; *B*, sheathing closed on wire core; *C*, electrode drawn down to finished size

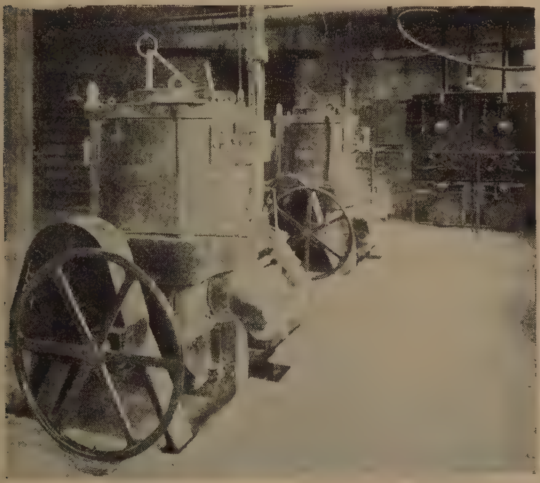

Fig. 33. Two 75-kw. Repulsion-induction Furnaces for Melting Brass

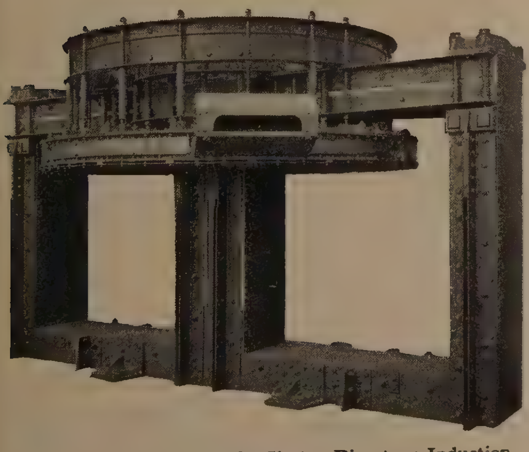

Fig. 34. Core and Coils for Six-ton Ring-type Induction Furnace

Fifteen 75-kw., 1200-lb. units of this type, Fig. 33, were placed in commercial operation in 1923 for melting non-ferrous metals, and a number of additional units were under construction. No changes were made in the electrical design, but exhaustive experiments were carried out in order to secure refractories best suited for this particular type of furnace.

A notable accomplishment of the repulsion-induction furnace was the successful melting of pure copper on a commercial basis.

The largest horizontal single ring type induction furnace in the United States, Fig. 34, was built for the Allegheny Steel Company. It has a maximum capacity of six tons and in normal service will melt three tons every three hours.

Current is supplied at 800 kw., 2200 volts, single-phase, 8½ cycles, by means of a specially designed synchronous motor-generator set. The motor of this set is rated at 1400 kv-a., 3-phase, and is operated at 80 per cent leading power-factor in order to compensate for low power-factor conditions in the electrical system of the mill in addition to driving the single-phase furnace generator.

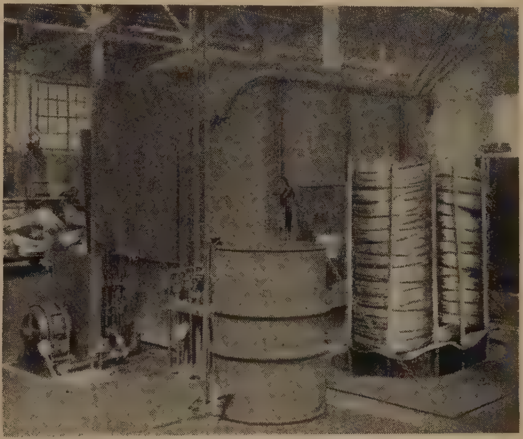

Fig. 35. Electric Furnace for Bright Annealing Copper Wire

In this way a low power rate is secured and the disadvantages of the inherent low power-factor of induction furnaces are avoided.

INDUSTRIAL HEATING

The electric furnace was for the first time successfully used for the bright annealing of copper wire.

The furnace, Fig. 35, which was especially designed for this particular work, is mounted on wheels and is moved back and forth over two hydraulic platforms. One of these platforms can be loaded while the other is in the heating chamber.

As the platforms enter and leave the bottom of the furnace through water, there is a water seal at all times to keep air from the heating chamber. The wire is uniformly annealed at all points in the furnace and the product is bright and free from scale.

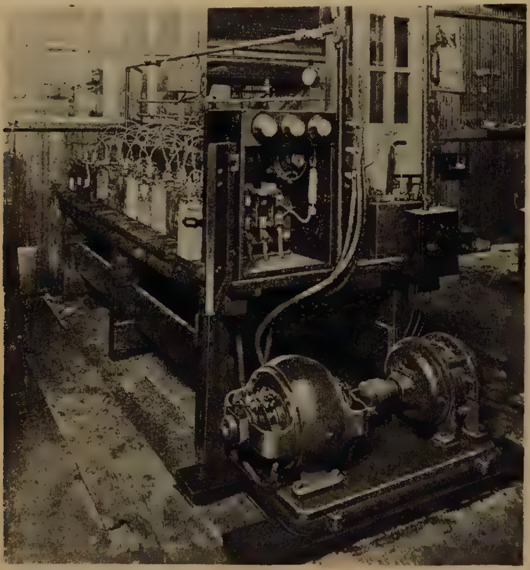

Fig. 36. Modified Constant-potential Battery Charging Equipment

The connected load is 300 kw., 550 volts, 3-phase and 7000 lb. of copper wire can be placed in the furnace at one charge and annealed in 1 hour and 15 minutes; the current required averaging about 1 kw.-hr. for each 25 lb. of wire.

Another special furnace was developed for annealing steel punchings used for field and armature laminations. It is built 6 ft. above the floor on a structural steel support and the laminations are placed on a car which is rolled under the furnace and raised into the heating chamber on a hydraulic platform. Around the edge of the car is a sand seal which makes the furnace air tight when the car is in place.

The heating chamber is 11 ft. long, 5 ft. wide, 3 ft. 6 in. high, with a connected load of 250 kw., 550 volts, 3-phase. Approximately 12 tons of laminations are heated per charge and the work is uniformly annealed.

This work was formerly done in oil furnaces. The cost of electric energy per ton of laminations annealed is considerably below the cost for fuel and, in addition to this, the cost of the heavy boxes usually necessary in the fuel furnace was eliminated. The elimination of these boxes also greatly reduced the floor space required for the heat treating operation. There was also a noticeable improvement in working conditions due to the absence of the smoke and noise inseparable from oil burner operation.

BATTERY CHARGERS

A new constant potential motor-generator 7½/15-volt battery charging outfit, Fig. 36, was produced, which includes a special regulator, Fig. 37, to maintain the voltage constant at the busbars, regardless of the number of batteries being charged.

This permits the use of shunt windings only on the generator thereby obviating any possibility of the reversal of polarity during power failure. The voltage to be held by the regulator is adjustable by means of a thumb screw.

The "Magnar" which is a mechanical rectifier of the vibrating type, used principally for charging storage batteries in railway signal service, was only experimentally installed in 1922, but during 1923, as a result of their demonstrated reliability, several thousand were utilized on more than 75 railway systems with entire success. Among the larger railroads, 1000 were supplied to the Illinois Central and 600 to the New York Central.

For charging the batteries of electric vehicles there was produced and standardized a new dead front type of panel board, Fig. 38, made up of removable steel sections.

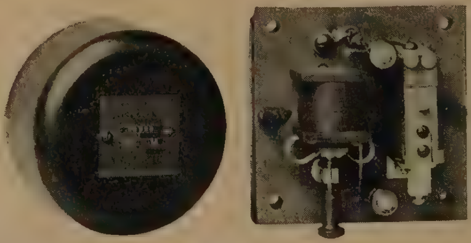

Fig. 37. Voltage Regulator Used with Charging Equipment shown in Fig. 36

Experience has shown that a safety type of control is desirable for this service even though the direct current potential may not exceed 115–125 volts. Therefore, the operating parts of this panel are not exposed and the various contactors are interlocked and electrically operated to insure simple, safe and positive control.

There are no unusual electrical features in the equipment but the panel is the embodiment of up-to-date switchboard practice adapted for the first time to the particular requirements of vehicle battery charging.

TRANSFORMERS

The recent tendency to concentrate the transformation of electrical energy in units of increasing capacity was evidenced by the construction of a large number of transformers of record size. A notable event of the year was the placing in service of the 220,000-volt, G-E units at Power House No. 8 of the Southern California Edison Company's system from which approximately 20,000 kw. was initially transmitted to Eagle Rock substation near Los Angeles.

There were under construction two self-cooled, three-phase, 60-cycle units which will transform 15,000 kv-a. as auto-transformers from 72,000 volts Y to 132,000 volts Y with solidly grounded neutral. Both of these windings will have taps. They will also transform 15,000 kv-a. from either of the high voltage windings to 12,470 volts and simultaneous operation on all three windings is possible. These transformers are larger in physical dimensions and in kv-a. rating than any self-cooled transformers heretofore built, the largest previous rating being 12,000 kv-a.

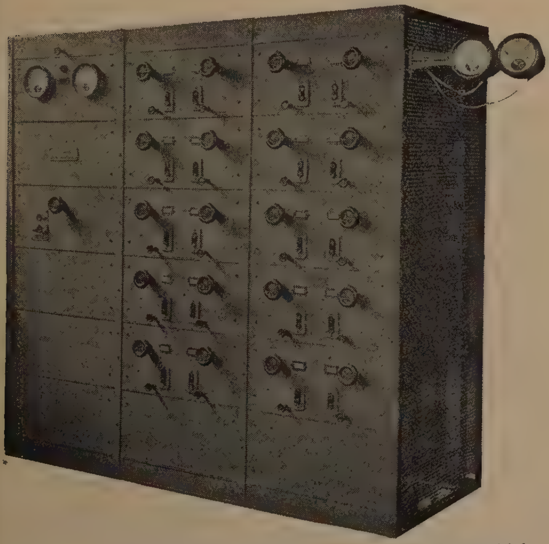

Fig. 38. Dead Front Type Panel Board for Electric Vehicle Battery Charging

Seven 60-cycle, 10,417-kv-a. single-phase, self-cooled auto-transformers of unusual construction were built for the Brooklyn Edison Company. They step up the generator voltage from 13,800 volts to 27,600 volts and have a normal rating of 10,417 kv-a., but since they are auto-transformers of a one to two ratio, each will transform a total of 20,834 kv-a. so that the total output of a bank of three units will be 62,502 kv-a. This is probably the largest amount of energy transformed by a single bank of self-cooled transformers.

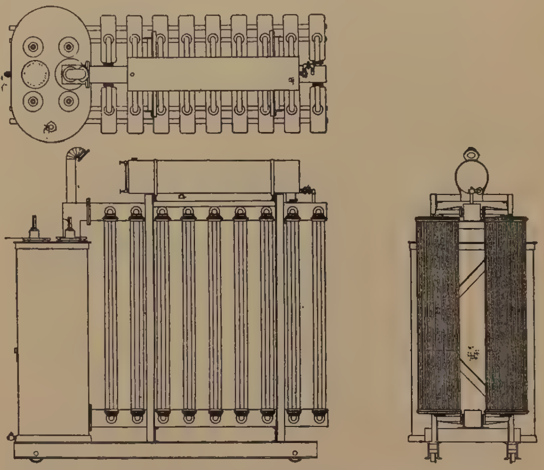

Fig. 39. Single-phase, Self-cooled, Auto Transformer showing Special Arrangement of Radiators

The transformer proper is contained in an oval steel plate tank but the radiators are banked separately and are only connected to the top and bottom of the tank, Fig. 39, by means of two large rectangular manifolds. The radiators and manifolds are supported on a structural steel framework and both tank and radiators are mounted upon a long truck.

When installed, the tank only will be in a cell and there will be a door or baffle between it and the radiators. This construction was dictated largely by space limitations but its adoption indicates the flexibility of design which is practicable for the cooling systems of large self-cooled units.

These transformers are also distinctive in the method of connecting the windings to the underground cables. Contrary to the usual practice of using standard outdoor porcelain bushings, they are designed so that the underground cables are brought, with their lead covering, directly into the transformer cover and connections are so made that no live parts are exposed. There are no switches between the transformers and the cables, all the switching being done at the generator end of the cable.

Eleven 18,750-kv-a., 102,000/6600-volt, 3-phase, 60-cycle water-cooled units were completed. They were shipped completely assembled and filled with oil despite the fact that they are the largest transformers of this type ever built and weigh approximately 70 tons each. See Fig. 40. The 18,750 kv-a. rating is on a 40-deg. rise basis, their capacity being 24,500 kv-a. at 50 deg. and in excess of 25,000 kv-a. at 55 deg.

The maximum capacity for single-phase, water-cooled transformers was increased by the construction of ten units, Fig. 41, rated 22,000 kv-a., 39,500/68,500/2300 volts, 25 cycles, for the Niagara Falls Power Company.

A three-phase air-blast transformer exceeding all previous units in both capacity and physical dimensions, Fig. 42, was built for the New York Edison Company. It is rated 17,100 kv-a., 11,800/2950 volts, 25 cycles.

The ratio adjuster was used for higher potentials and heavier currents, the maximum for 1922 being 110,000 volts, 500 amperes; and for 1923, 150,000 volts, 1200 amperes.

For many years there has existed a demand for a means of changing voltage under load without being required to cut transformers out of circuit. In the past, the desired result has been accomplished generally by using induction regulators or by bringing the taps outside the transformer case and changing tap connections by means of switches and reactors. The induction regulator gives the best possible method of changing voltage

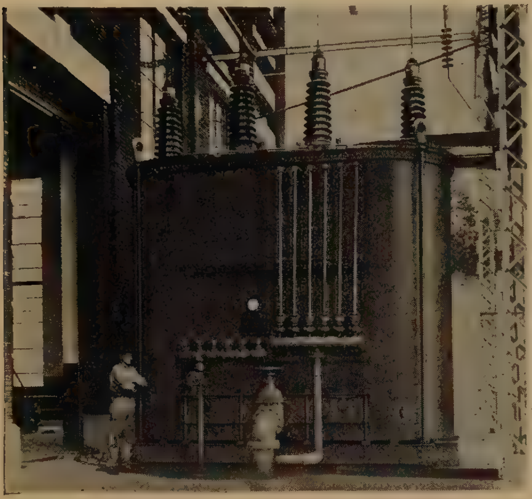

Fig. 40. Three-phase, Water-cooled Transformer Rated 24,500 kv-a. at 50 Deg. Rise

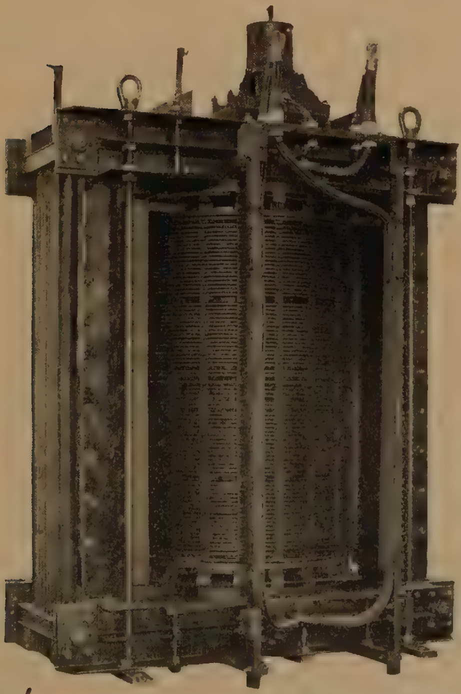

Fig. 41. Single-phase, Water-cooled Transformer Rated 22,000 kv-a. 39500/68500/2300 volts, 25 cycles

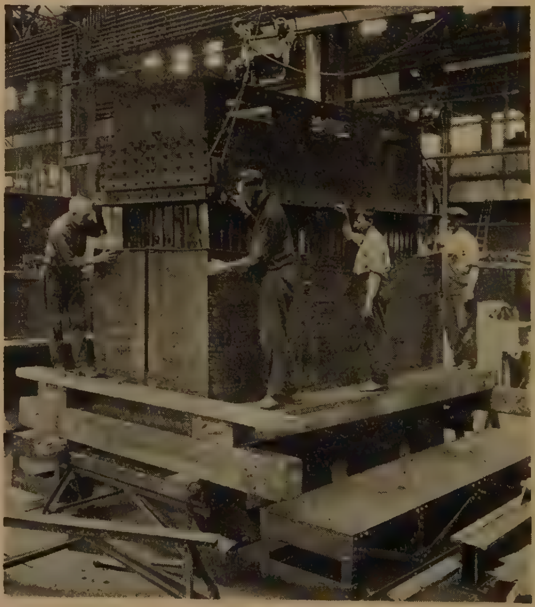

Fig. 42. The Largest Three-phase Air-blast Transformer, Rated 17100 kv-a., 11800/2950 volts, 25 cycles

under load, but both the induction regulator and the reactor tap changing schemes are expensive, and a scheme of tap changing which would accomplish the desired result but at much less expense is, therefore, very desirable even if the voltage curve is not so smooth.

Eight 15,000-kv-a., and two 20,000-kv-a., three-phase transformers were designed for the Commonwealth Edison Company with two parallel connected circuits in one of the windings, with leads brought out to switches so that either half of the winding can be disconnected from the load while the taps are being changed on that portion of the winding; the other half of the winding carrying the load current during this operation.

The following is a brief outline of the principle and sequence of operation of the tap switching mechanism: The high voltage winding is designed for 33,000 volts Y connected, and is provided with four 2½ per cent taps above and four 2½ per cent taps below this voltage, the winding being divided, Fig. 43, into two similar parallel circuits in each phase. The two parallel circuits in each phase are connected together at the line ends, as shown at H_1, H_2, and H_3. The taps are located at the neutral ends of the windings, and connected to dial switches (a-a′-a″) and b-b′-b″). Switches (a-a′-a″) are mounted on a common shaft, but insulated from each other, and switches (b-b′-b″) are mounted similarly on another common shaft.

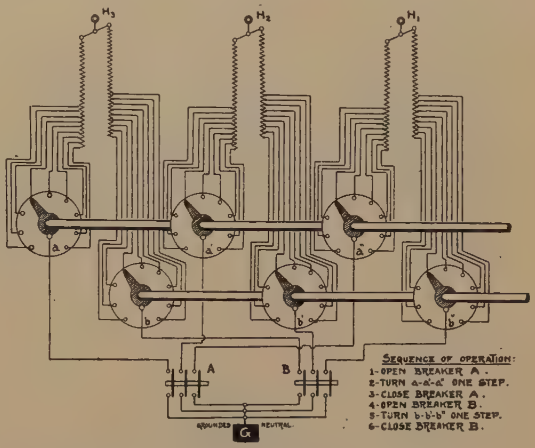

Fig. 43. Diagram showing Sequence of Operations of Tap Switching Mechanism

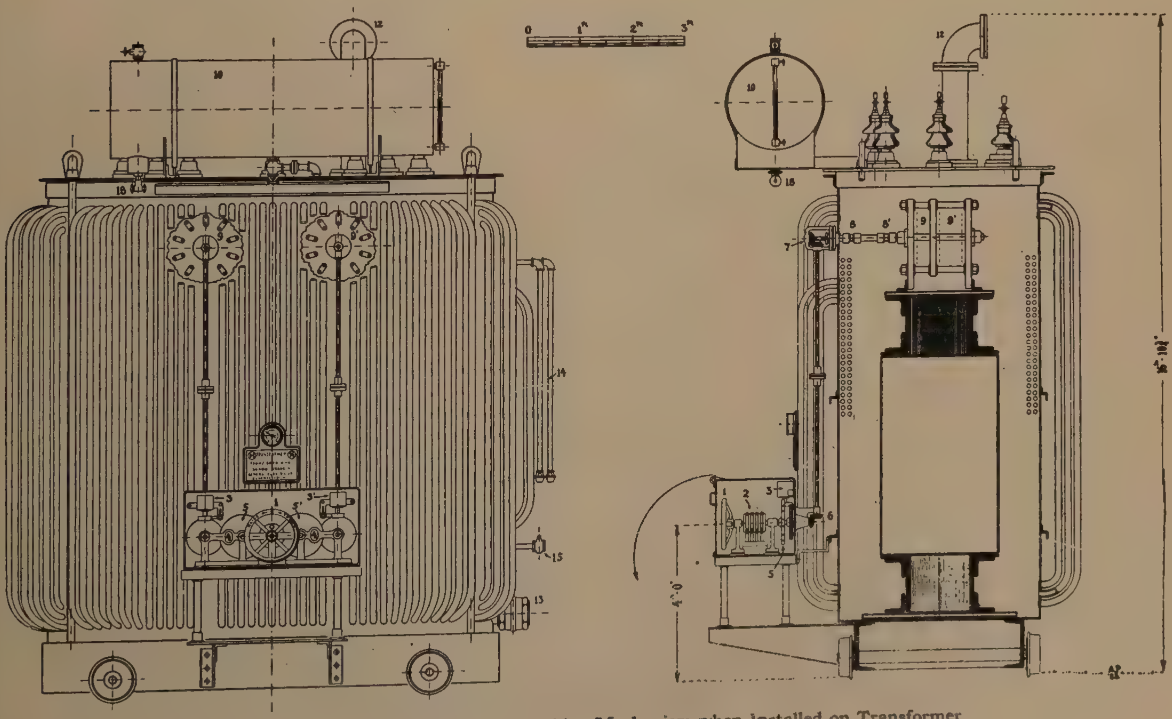

Fig. 44. Arrangement of Tap Switching Mechanism when Installed on Transformer

Leads from the revolving blades of the dial switches are brought out through the cover through bushings and are connected to two oil circuit breakers A and B. When circuit breakers A and B are closed, which is their normal position, all rotating blades of the dial switches are connected solidly to ground.

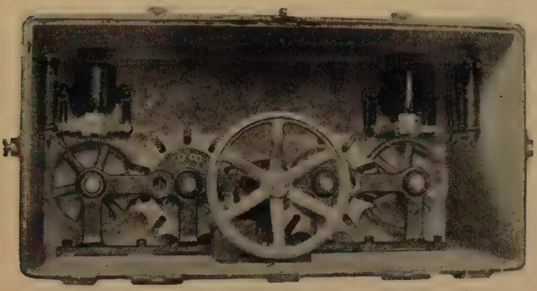

Fig. 45. Handwheel and "Geneva" Gear Train for Control of Tap Switching Mechanism

The tap switching mechanism includes six dial switches which are located within the transformer on top of the core, Fig. 44, and supported on the core clamping structure. Each of the two common shafts for the two banks of three dial switches is brought through a stuffing box in the tank near the top. Universal joints are provided between the switches and the stuffing boxes take care of slight variations in the alignment. The mechanism for controlling the operation of the circuit breakers and driving the dial switches is located at a convenient distance from the floor level, and is connected to the dial switches by means of two vertical shafts and two sets of bevel gears. The mechanism is a part of the complete transformer, and is supported from the truck and braced from the tank.

A single handwheel, Fig. 45, drives two large "Geneva" gears, each of which through suitable gears drives the corresponding bank of dial switches. When the handwheel is turned, first one of the "Geneva" gears, and the connected bank of dial switches is moved one step, following by similar motion of the other gear and its connected bank of dial switches. A complete revolution of the handwheel moves each bank of dial switches one step. This "Geneva" gear arrangement makes it impossible to move both banks of dial switches at the same time, and also insures their being not more than one step of 2½ per cent apart, and when a complete turn of the handwheel is made, insures that all dial switches will be connected to the corresponding taps.

The oil circuit breakers, A and B, Fig. 43, which connect the dial switches to the grounded neutral are interlocked, so that it is possible to have only one circuit breaker open at a time, thereby preventing complete interruption of the load; differentially connected relays will indicate an incompleted cycle of operation and the handwheel may be reversed at any point during a revolution and brought back to its normal position without trouble so that an operator may safely change his mind in the midst of an operation.

An interesting form of construction was adopted for three water-cooled 15,000-kv-a., 118,800-volt transformers for the Northern States Power Company, which were shipped complete in their oil although the transformers were five to six feet higher than allowed by the railroad clearances. This was accomplished by using a two-section tank, the lower end of the top section being slightly above the level of the core and coils, thus allowing the top section to be removed and the cover bolted to the lower section for shipment. On arrival, the top section, containing its own cooling coil unit, was joined

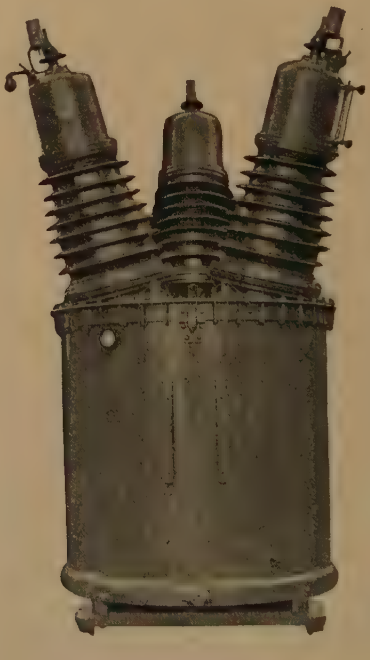

Fig. 46. Metering Outfit for 90,000-volt System of Paris-Orleans Railway

to the lower section without removing the oil from the latter.

There was further demonstration of the value of concentric circular windings for extra high-voltage transformation. The marked advantages of this type over the interleaved (sandwich) type had been brought out in studies of impressed high-voltage transients on commercial transformers, this work being carried on in the high-voltage laboratory. The unique equipment of this laboratory has placed high voltage transformer design on a scientific basis heretofore unattainable and has made possible the absolute checking of calculated phenomena. The same studies also advanced the use of the "built in" protective devices.

An unusual arrangement of instrument transformers was provided for metering energy on the high potential side of substations on the Paris-Orleans Railway. Four 60,000-volt transformers each have three current and two potential transformers, while two 90,000-volt units, Fig. 46, have three each of current and potential transformers mounted in a single tank with three high-voltage leads.

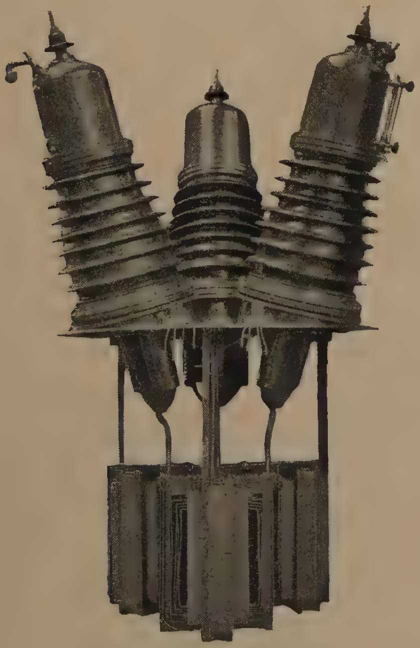

Fig. 47. Current Transformers Installed Inside the Porcelain Leads of the 90,000-volt Metering Outfit

The 90,000-volt arrangement is unique in that the three current transformers are located inside the porcelain bushings, Fig. 47, whose headers also serve as oil conservators.

In view of the severity and importance of the service required of these instrument transformers they were constructed with safety factors fully comparable with those used in power transformers.

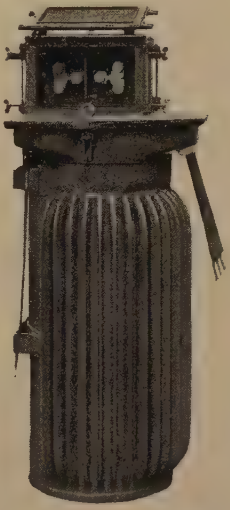

Fig. 48. Transformer Equipped with Improved Type Alternating-current Network Protector

The alternating-current network protector, which serves to disconnect a defective transformer which would otherwise act as a short circuit on the system and progressively blow the fuses of the other transformers in the network, was improved to facilitate re-fusing in locations where headroom is limited.

Initial installations of the network protector have been in service for several years and the improved type, Fig. 48, embodies the changes indicated by experience. About 6500 kv-a., in 50, 75, and 100 kv-a., of these units were installed, permitting a wider adoption of alternating-current network systems by eliminating the one serious obstacle to their extensive use.

What is probably the largest order ever received for lighting service transformers included 5000 15-kv-a. and 55 2000-kv-a., 50-cycle units for use in the rebuilt city of Tokio, Japan.

The average unit size of self-cooled transformers continued to increase but due to specific conditions the average for all types was somewhat reduced as compared with 1922. Table I shows the average ratings for the past five years.

TABLE I

AVERAGE UNIT SIZE OF POWER TRANSFORMERS IN KV-A.

Year	Self-cooled	Water-cooled	All Types
1919	1175	4325	2150
1920	1325	3175	2175
1921	1575	4150	2750
1922	1700	6000	3750
1923	2350	5125	3220

At the close of the year there had been completed or were under construction a total of more than 180 units of 10,000 kv-a. or above.

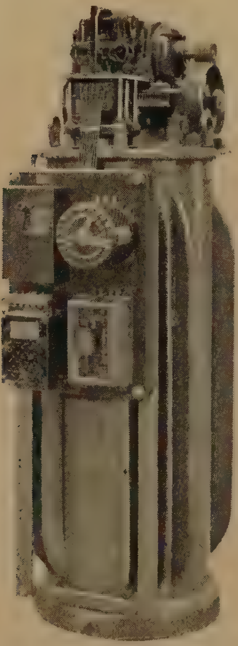

Fig. 49. Single-phase Induction Voltage Regulator Embodying all Recent Improvements

INDUCTION VOLTAGE REGULATORS

A new design of single-phase induction voltage regulator, Fig. 49, was developed, which embodies a number of improvements as compared with previous types. In addition to improving the voltage regulation by a more rapid correction of voltage changes, it utilizes a tank which is highly resistant to rupture as a result of explosions, and a rigid internal mechanical structure to minimize noise during operation. An improved method of bracing the coils prevents insulation troubles due to line short circuits.

The tank is of all-welded steel, constructed of boiler plate with heavy flattened steel boiler tubes for radiation, and advantage was taken of the efficient heat radiating qualities of the tank to reduce the height of the regulator and thereby secure a more rigid mechanical structure combined with increased accessibility of the operating mechanism.

The motor used on these regulators has a cast aluminum rotor winding which renders possible an increase in the motor speed from 900 r.p.m. to 1200 r.p.m. thereby effecting a reduction of the time of operation from limit to limit of the regulator from eleven seconds with the old type to eight seconds with the new. The motor has extremely rapid acceleration and deceleration, important factors when making voltage corrections.

LIGHTNING GENERATOR

The lightning generator installed in the High Voltage Laboratory of the Pittsfield Works will produce voltages of approximately 2,000,000 above ground. This is perhaps higher than lightning voltages that are usually produced on transmission lines. These voltages are of a known wave shape and duration. The wave front is under control and may be made so steep that the voltage starting at line voltage may be made to increase at the rate of 50 million million volts per second. The rate that energy is dissipated in the arc is generally of the order of millions of horse power. The duration of such discharges is conveniently measured in microseconds (millionths of seconds).

The discharge, which takes place with an explosive report, has all of the characteristics of lightning such as side strokes, etc. Large wooden posts are readily split and blown apart.

The generator, Fig. 50, offers a very useful tool in investigations to discover how best to protect against lightning and how best to build apparatus to withstand lightning. It is also useful for studying the ground wire used on transmission lines and the lightning rod.

LIGHTNING ARRESTERS

A new type of oxide film arrester, known as the pellet arrester, was developed commercially. In this arrester, Fig. 51, the lead peroxide, which is the active element of the oxide film type of arrester, is utilized in the form of small pellets about one-eighth of an inch in diameter, which are covered with litharge. This litharge coating acts like the varnish film on the plate type of oxide film arrester and thus each pellet becomes a small oxide film cell. The pellets are put into a porcelain container and are connected to the line through a gap.

From the standpoint of discharging lightning these arresters appear to have about the same characteristics as the plate type of oxide film arrester and in addition have the advantage of requiring somewhat less space so that they are more readily adaptable for pole mounting. Installations of these arresters were made on 3000-volt and 15,000-volt circuits.

REACTORS

The electrical characteristics of cast-in-concrete reactors were not altered but due to space limitation there were some special assemblies of three-phase units, Figs. 52 and 53, which gave the necessary adaptability without any sacrifice in efficiency.

It often happens in power stations that the space available for installing current limiting reactors is quite small in width, while the height and depth are greater. This occurs when the reactors must occupy cells with the same width as switch and regulator cells. In such cases space is economized by assembling the reactors with their longitudinal axis horizontal. The reason for this is that the lengthwise dimension of the reactor can be made small, if the diameter is made large. Such a reactor is assembled with its lengthwise dimension in the direction of the width of the space, while the diameter dimensions extend in the direction of the depth and height. Hence the reactor can be placed in a cell which is too narrow to permit it being installed vertically. This is also true in the case of a three-phase reactor, where the width of cell required will be less than the width of cell for the usual type having the three phases assembled side by side.

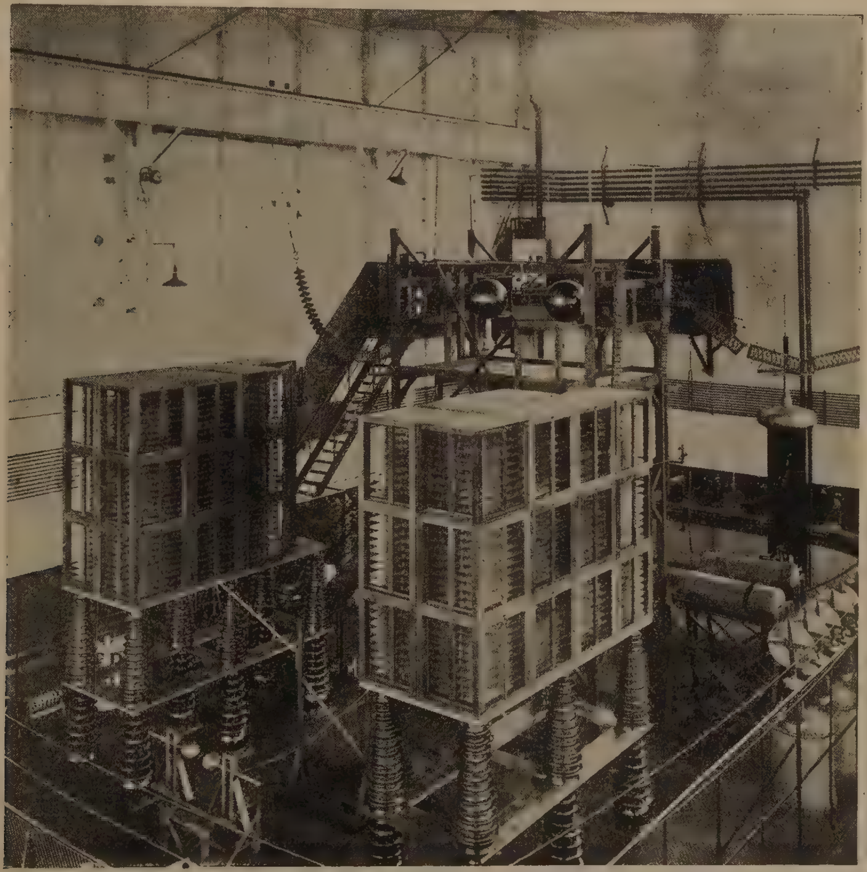

Fig. 50. Lightning Generator in High-voltage Engineering Laboratory

A reactor having a large diameter and a short length gives a greater reactance from the same length of conductor than a reactor with a small diameter and a large length. For this reason the first-mentioned type in a horizontal position is very efficient from the standpoint of economizing copper and losses.

The use of the standard G-E Reactor-Resistor combination, which is simply a concrete reactor with a selective resistor in parallel, was further extended. This device performs the normal function of the reactor, i.e., the limiting of abnormal currents, and also acts to consume the energy of transient high frequency voltages by means of a series of special resistance rods which present a high resistance to the normal voltage and a low resistance to high voltages caused by high-frequency disturbances.

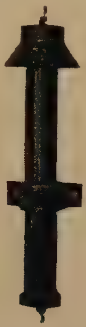

Fig. 51. Oxide-film Pellet-type Lightning Arrester for 7500 to 15,000-volt Service

The use of reactors alone, especially in feeders connected to overhead lines, is always accompanied by more or less danger of local voltage rise because the reactor acts as a reflector to high-frequency voltages or steep wave impulses. Without the resistor such disturbances may be reflected several times and rise to dangerous values when trapped between the reactor and other inductive apparatus.

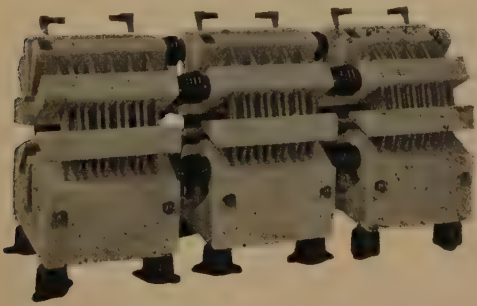

Fig. 52. Special Assembly Arrangement of 27-kv-a. Reactor

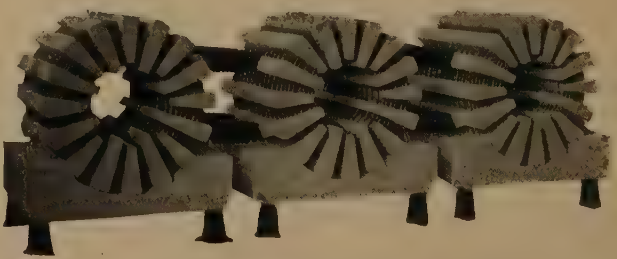

Fig. 53. Reactor Units Assembled with Longitudinal Axes Horizontal

X-RAY TUBES

A new tube having 15 times the X-ray energy of the average tube now in commercial use was produced for therapeutic work.

It is rated 250,000 volts, 50 milli-amperes, and is provided with cooling coils which carry the circulating water direct to the back surface of the anode. It is the first high voltage tube equipped with a cooling system of this type.

The new tube has not yet been developed commercially, but has been used experimentally for several months. The previous maximum size, rated 200,000 volts, 8 milli-amperes, is now in commercial production.

PHOTO-ELECTRIC CELL

An extremely sensitive photo-electric cell was developed, consisting of a small bulb into which two electrodes are sealed. The inside walls of the bulb are coated with silver with the exception of a very small area which is kept clear for the passage of light.

The action of light focused on the cell through the clear spot causes increasing electron discharge from cathode to anode with potentials as low as 50 volts. Due to the sensitivity of the cell very slight variations of light cause the current to change very rapidly. By using vacuum tube amplifiers the current from the cell can be increased to any value desired.

This photo-electric cell has already been applied commercially in the mechanical sorting of cigars according to color. The process is as follows: The cigars are carried on a mechanical conveyor and at a certain point a beam of light strikes a cigar. The light reflected from the cigar falls on the eye of a photo-electric cell and since the cell current changes as the light intensity varies, the current from the cell, through an amplifier, causes mechanical gates to operate through which the cigars fall into boxes graded according to color. By means of this device, it is possible to sort cigars much faster and more accurately than by hand or by any other method heretofore devised.

CONDUCTOR CABLE

As the result of exhaustive research work, the manufacture of 66,000-volt single conductor cable was for the first time placed on a commercial basis in the United States.

The cable produced was for the Cleveland Electric Illuminating Company and can transmit upwards of 33,000 kw. at 66,000 volts. It is slightly over three inches in diameter and requires 250,000 volts to puncture.

The previous maximum potential for conductor cable in the United States was 44,000 volts; cable of this rating being utilized for the underground circuits of the New York Edison Company.

HIGH-VOLTAGE DIRECT-CURRENT CABLE TESTING SETS

The purpose of direct-current testing sets is to permit power companies to make satisfactory periodic tests of underground cables, to determine the condition of insulation between conductors, between conductor and ground, to locate cable faults and to measure insulation resistance. Three types of equipment were developed and standardized for this service.

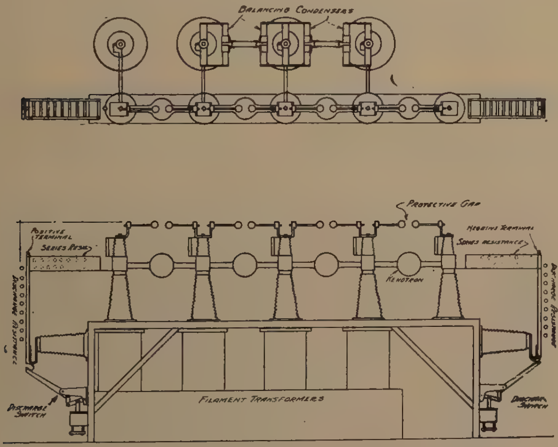

Fig. 54. Outline of 200,000-volt Direct-current Cable Testing Set

For station use, to be considered as a stationary outfit, a four-kenotron 200,000-volt set, Fig. 54, was designed, each Kenotron being capable of rectifying 250 milli-amperes direct current.

For cable testing this set is used in the following manner. During one-half cycle the current flows through two kenotrons in series and charges one conductor, during the other one-half cycle current flows through the other two kenotrons and charges the other conductor with the reversed polarity, so that the voltage between the conductors will be twice the crest value of the transformer voltage. The voltage across the two kenotrons in series on the reverse wave will be the transformer voltage plus the voltage from the conductor to ground which will be a maximum of 200,000 volts.

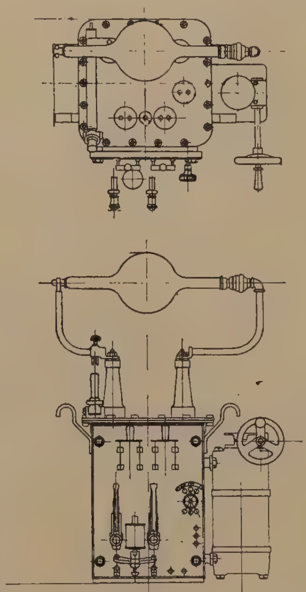

Fig. 55. Outline of 30,000-volt Direct-current Cable Testing Set

The direct-current voltage is measured by special meters which measure the crest value of the voltage wave obtained from the voltmeter coil. Two meters are used, each meter reading the voltage from conductor to ground and the voltage between conductors is the sum of the two readings of the voltmeters. The current supplied to the cable is measured by two ammeters connected between the ground and the transformer winding. In series with each meter is a tungar rectifier which divides the current so that one-half wave flows through one meter and the other one-half wave flows through the other meter. In this way the current supplied to each conductor is measured separately.

A smaller set rated at 100,000 volts and 100 m.a. is semi-portable and can be moved around a station or moved from one station to another by truck. It functions in essentially the same manner as the 200,000-volt set except that it is limited to lower voltages and current and only two kenotrons are used.

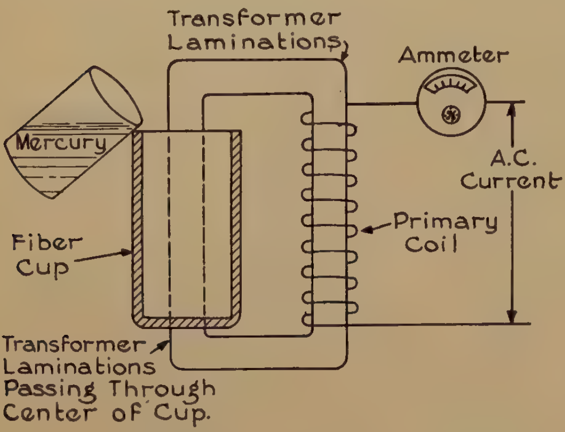

Fig. 56. Illustration of the Transformer Principle Employed in the Electrically-operated Flow Meter

For portable testing a 30,000-volt set, Fig. 55, using the 100-m.a. kenotron was designed primarily for measuring insulation resistance and not for high potential testing. By means of this type of equipment, it is possible to locate cable faults which can later be given further tests by means of one of the higher power equipments.

ELECTRICALLY-OPERATED FLOW METERS

A type of electrically-operated flow meter with many new characteristics was developed for measuring accurately the total flow of steam, water, air, gas, oil, etc., through pipes and so furnishing information of great value in the economical management of any manufacturing industry or central station. It does not supersede the mechanically operated flow meter, but is simply an addition to existing types.

Due to the electrical principle of operation the indicating curve drawing and integrating instruments can be located at any distance away from the pipe where the flow is being metered and the instruments can be either separated, grouped or duplicated.

The meter consists of three principal elements: The flow nozzle installed in the pipe, and like those used with mechanically-operated flow meters, the cast iron meter body piped to the differential pressure producing device and the electrical measuring instruments mounted on the panel.

To illustrate the transformer principle employed, consider a simple core type transformer, Fig. 56, having a primary coil wound on one leg and a fiber cup surrounding the other leg. If the primary coil is excited by alternating current, the ammeter in series with this coil measures the excitation current required to supply the transformer losses. If mercury is poured into the fiber cup forming a ring around the laminations passing through its center, current will be induced in this mercury ring directly proportional to its resistance, if primary resistance and magnetic leakage are neglected. The current flowing in the primary circuit, measured by the ammeter, will necessarily be increased to supply the current in the mercury ring. As more and more mercury is poured in the fiber cup the resistance of the mercury ring is decreased because its cross-section is increased and more and more current will be required in the primary circuit to supply that induced in the secondary mercury ring.

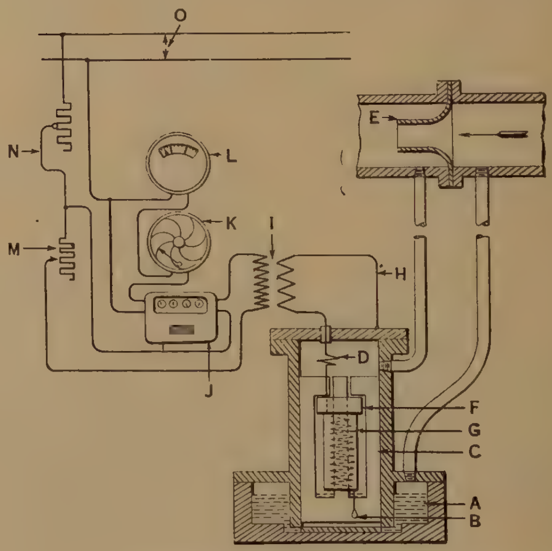

Fig. 57. Diagrammatic View of Electrically-operated Flow Meter

A	Mercury
B	Ground connection of primary coil
C	Transformer laminations
D	Flexible rubber covered lead to primary coil
E	Flow nozzle producing a differential pressure
F	Insulating compound covering primary coil
G	Primary coil
H	Ground connection of transformer
I	Transformer mounted on meter body, 108/5 volts
J	Watthour meter
K	Curve drawing ammeter
L	Indicating ammeter
M	Adjustable resistance compensating for line drop
N	Voltage regulator resistance in series with line
O	Alternating-current supply

It is, therefore, evident that the ammeter can be so calibrated as to measure the height of the mercury ring in the fiber cup.

In the commercial form of flow meter body, Fig. 57, a three-legged core type transformer is used instead of a two-legged one and the primary coil is mounted on the middle leg of the laminations. The cast iron meter body containing the mercury and internal transformer is so made as to form a U-tube, the base or mercury well forming one leg and the smaller chamber, in which the transformer is inserted, the other. The base or large leg of the U-tube is connected to the upstream side of the flow nozzle and the small or transformer leg to the downstream side.

On the outside of the meter body a small transformer is mounted whose function is to reduce the voltage applied to the internal transformer in the meter body as well as to act as an insulating transformer. A potential of 108 volts, held constant by means of a voltage regulator, is applied to the primary of this transformer while the secondary voltage applied to the primary coil of the transformer in the meter body is less than five volts.

In series with the primary of the outside transformer are the adjustable line resistance, voltage regulator resistance and electrical measuring instruments.

When there is no flow of gas or fluid through the main pipe, the electrical instruments indicate the excitation current and the zero readings on the instruments and meters are suppressed so that zero flow corresponds to this excitation current. When the gas or fluid flows through the pipe there will be a differential pressure produced by the flow nozzle which causes the mercury in the meter body to rise in the transformer leg and fall in the base until the unbalanced column balances the differential pressure.

As the mercury ring rises around the primary coil of the internal transformer, more and more current is induced in it which must be supplied through the primary circuit, the action being similar to pouring mercury in the fiber cup.

By proper calibration the electrical instruments will measure accurately the height of mercury in the small leg of the U-tube containing the internal transformer, which height is a function of the flow of gas or fluid in the pipe.

The inevitable accumulation, in time, of foreign matter, such as iron rust, pipe scale, etc., on the surface of the mercury in the meter body will have no detrimental effect on the meter's operation unless it reaches such an amount as to stop up the small pipes connecting the meter body to the flow nozzle. An accumulation in sufficient quantities to stop up these pipes would take years under ordinary conditions. No oil is used on top of the mercury.

RADIO

The improvements in vacuum tubes for radio purposes were mostly in the direction of increased efficiency of operation and a general betterment of electrical characteristics.

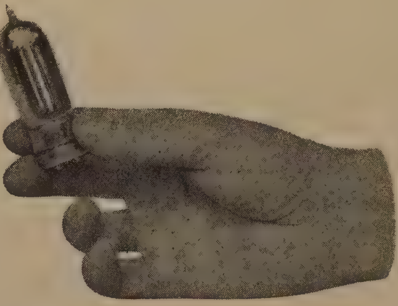

Fig. 58. The Smallest Standard Receiving Tube (0.18 Watt)

It is also interesting to note that during the year there was started in regular production a new tube of the highest power so far standardized, and also the smallest tube requiring the least power expenditure in the filament that has so far been made available to the public for radio receiving sets.

The smallest standard receiving tube, UV-199, Fig. 58, operates with an expenditure of only 0.18 watts for the filament which is of a new type and insures high electron emission, silent operation and long life.

The development of the new filament made possible the remodeling of the Radiotron UV-201, the previous standard receiving tube, so that it only required one-quarter the former amount of filament power. At the same time the characteristics of the tube were changed so that it became a better detector and amplifier.

A new highly efficient 50-watt transmitting tube, UV-203-A, was developed and put into production. This tube also incorporated the new filament which enabled the filament energy required to be cut to one-half its former value for this size of tube and at the same time the characteristics were greatly improved. The operating life was also increased several fold by the change to the new filament.

A new tube, UV-204-A, of 250 watts output also employed the new filament which decreased the power consumption to about one quarter of its former value and also improved the life.

A transmitting tube of 20 kw. output operates from a direct current source of 12,000 to 15,000 volts. In this tube, UV-207, the anode is also the container and the tube is designed to operate with the anode container immersed in running water so as to dissipate the heat developed in the interior of the tube. Several of these equipments were placed in service and more than a dozen other sets were being installed or were under construction.

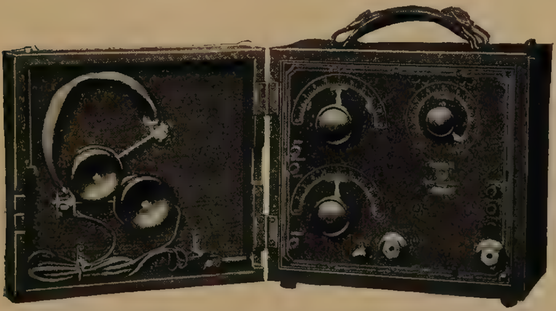

Fig. 59. Portable Self-contained Receiving Set with Telephones and Plug in Front Cover

Many important improvements were made in the design and production of radio apparatus, the advances being especially notable in broadcast receivers. The public's interest in broadcasting continued unabated and the demand for apparatus was so insistent that a considerable number of new styles were standardized.

The sectional units which were formerly standardized were combined in various groups so as to meet different requirements. One of these units, a detector amplifier, was used in conjunction with the tuning unit, and suitable means were devised for combining the two to form a receiver set suitable for use with an outside antenna. The set is very simple in operation, having a single tuned circuit and is provided with regeneration when operated with a tube detector. A crystal detector is a part of the receiver for giving head telephone reception on near-by broadcasting stations when desired. These sets were adapted for the dry battery radiotrons, thereby entirely eliminating the necessity for storage batteries.

Another set was made by combining the same detector amplifier unit with a three-stage radio frequency amplifier unit to make a set suitable for use with a loop aerial. This set is very simple in operation, there being but one tuning control, the variable condenser in parallel with the tuning loop.

New component parts were added to the line of standardized parts already available for use by amateurs and those desirous of constructing their own sets. The principal additions included socket and rheostats for the new low filament current radiotrons as well as adapters for using these tubes in the sockets originally supplied in many sets.

A loud speaker was developed for use as an addition to sets not already equipped with one. It is very sensitive and reproduces signals with clear quality and a single adjustment is provided for the diaphragm, which gives good operating efficiency over a considerable range of signal intensities.

Early in the year, the requirements for receivers took on a new aspect. Portable and self-contained receivers had become possible due to the new tube developments, and these suddenly were widely demanded. The receiver designed to meet this need, Fig. 59, utilizes a single-circuit regenerative system with a detector and an audio-amplifier tube, functioning well over the broadcast range. The method of control is exceptionally simple. The telephones and plug are carried in the front cover, while the batteries are in the rear. Having a complete weight of but 18 lb., the set is made easily portable by the addition of a leather carrying handle.

The small crystal receiver previously standardized was also adapted to meet the changing demand. It is now housed in a wood case, and is fitted with a carrying handle for portability; the telephones being carried in a compartment in the rear cover.

Perhaps the best example of the adaptation of the new radiotrons to a complete receiver is to be found in the self-contained cabinet receiver which utilizes a single circuit tuning system with regeneration and has a detector and two audio frequency stages. The batteries are supported inside the cabinet, and the loud speaker is built into it. The tuning controls, two in number, are easily accessible.

Developments in the line of commercial receivers included the standardization of those used in the trans-Atlantic and trans-Pacific stations of the Radio Corporation of America.

The layout of these communication channels consists of three separate divisions; first, the transmitting station usually located at some advantageous position near the coast for sending the communications across the sea; second, a receiving station, also advantageously located for reception from across the sea, but usually removed from the transmitter; and third, the operating division, usually located in the heart of the business or financial center to which the communication service is to be rendered.* The operating division may frequently be separated by 100 to 200 miles from either of the two other divisions, but it directly controls through suitable remote-control relays the operation of these two divisions. Thus, communication is directly carried on from the desired point, without transcription by the other divisions.

The equipment in the receiving stations consists of eight separate large units, not including the relays necessary for transposing the signals on the land wires.

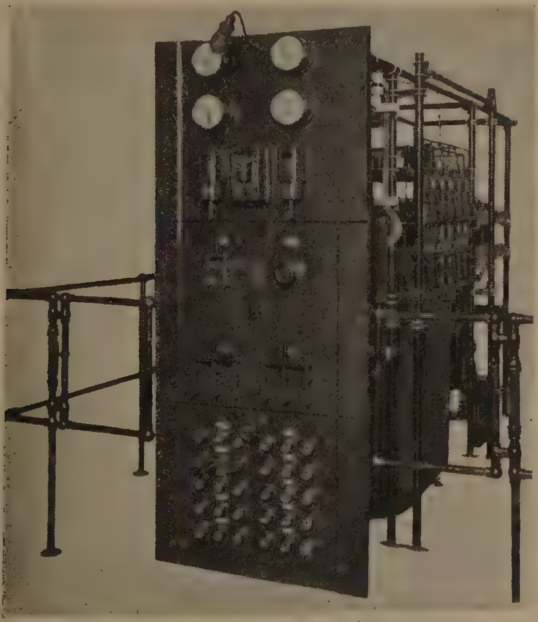

Fig. 60. 30-kw., 15,000-volt Kenotron Rectifier Complete with Controls

It is interesting to note that both the stations which took part in bringing the news of the recent Japanese disaster in September, 1923, to the world, were equipped with the above standard receiving equipment. On the Japanese side, the operating division of station JAA was located in Tokio, while the transmitting division was in Haranomachi some 155 miles away, and the receiving division 187 miles away at Tomioka. On the American side, a similar situation existed. Station KET has its operating division in San Francisco, its transmitting station at Bolinas, about 50 miles away, and its receiving station at Marshall, 44 miles away.

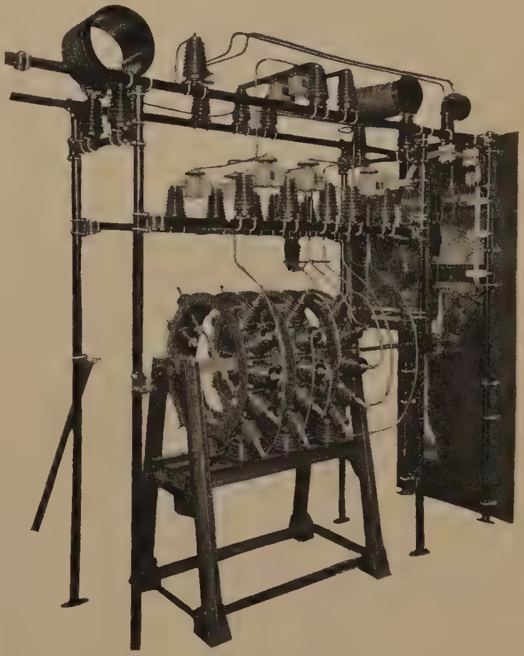

Fig. 61. Master Oscillator Unit for 10-kw. Vacuum-tube Telegraph Transmitter

Station JAA usually works through the Radio Corporation station at Koko Head, Honolulu, but in this emergency communication was carried on directly across the water. The personnel of both stations worked incessantly at fever heat, while Japan told of her terrible calamity and needs. With all other communication systems out of order radio stood as the only means by which the call for assistance could be brought to mankind.

For the purpose of securing a high voltage direct-current supply for the operation of radio vacuum tube transmitters, and for experimental work, there was developed and built for the U. S. Navy Department, a kenotron rectifier, rated at 30 kw. at 15,000 volts direct current. It contains twelve Model UV-218 kenotrons, so connected that so-called 3-phase full wave rectification is obtained.

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*See also GENERAL ELECTRIC REVIEW, January, 1922, Vol. XXV, No. 1, page 52, for a further description.

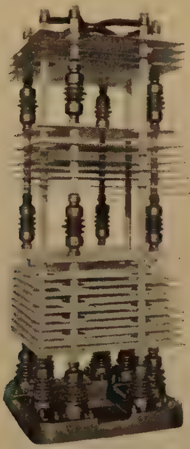


Fig. 62. Intermediate Circuit Air Type Condenser

The rectifier, Fig. 60, has associated with it the necessary controls, whereby its output can be adjusted from full output to a small fraction thereof. The filter system is associated with the rectifier, which smooths out the remaining ripple in the rectified alternating current to less than one-tenth of one per cent. This rectifier is now installed in the Navy Department Laboratories at Bellevue, near Washington, D. C.

As a link in the communication system of the U. S. Signal Corps, there was built for installation at Fort Douglas, Utah, a 10-kw. vacuum tube telegraph transmitter, Fig. 61. Many novel features of construction were included due to the wide band of wavelengths which it covers, and to the necessity for including switching mechanism whereby wavelength (frequency) could be readily changed to any one of five predetermined values. Air condensers, Fig. 62, of a new design were utilized.

A number of vacuum tube telegraph transmitters were built for the communication system of the United Fruit Company. These transmitters are mostly installed in Central and South America, and will, when in service, form what will probably be one of the most modern commercial radio communication systems in existence. They have an output of 20 kw., Fig. 63, at any wavelength between 2500 and 4500 meters and include switching mechanism, so that any one of two predetermined wavelengths can be readily obtained.

The sets include recently developed circuits which insure constant frequency of the output, and the practical elimination

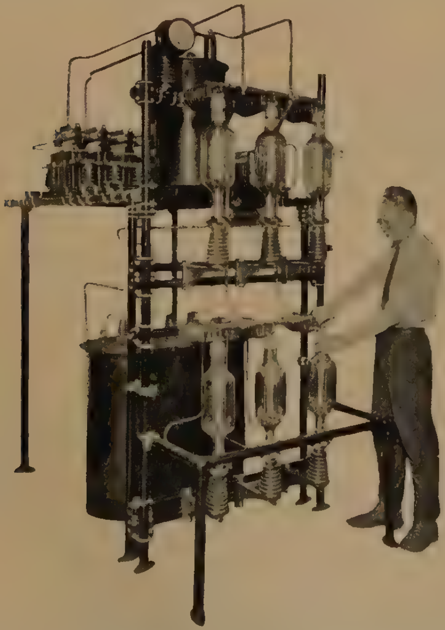


Fig. 63. 20-kw. Vacuum-tube Telegraph Transmitter Rectifier for Wavelengths of 2500 to 4500 Meters

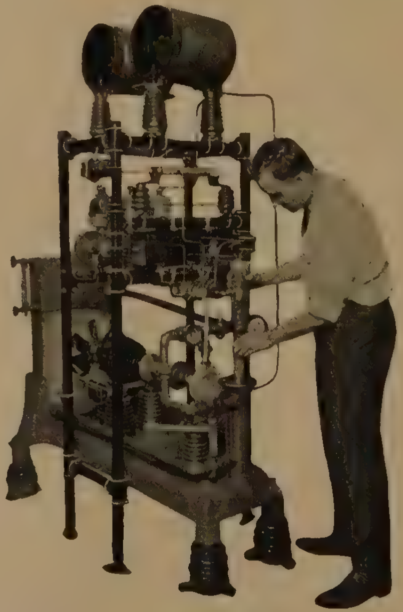


Fig. 64. Water-cooled Tube Unit for 20-kw. Transmitter

of harmonics. The transmitters consist primarily of a so-called "master oscillator," the output of which is amplified by means of a water cooled pliotron, Fig. 64, which delivers its output to a "tank" circuit, which is coupled to the antenna. They are designed to operate on antennas of the multiple tuned type, having two tuning points.

In connection with the air mail service of the U. S. Postoffice Department, there was designed an aircraft transmitter and receiver for use on the airplanes. The transmitter of this equipment puts approximately 200 watts into a trailing wire antenna. The power for the operation of the set is obtained from storage batteries which are kept charged by the engine of the plane and these batteries operate a high voltage dynamotor, which supplies high voltage direct current power for the operation of the transmitter.

The set consists of three major units—the transmitter, receiver and control box, together with a number of auxiliaries. The equipment was designed so that it can be advantageously installed in the fusilage of the plane, and so that maximum accessibility is given to the operator. The planes which will utilize the sets are built to carry the pilot only, and it was necessary to develop and design this equipment so that it can be readily operated by the pilot without interfering with the navigation of the plane.

CARRIER CURRENT

The carrier current system of telephony, which effects communication by means of high frequency currents superimposed on the power conductors of transmission lines, was applied over greater distances than heretofore by the production of a 250-watt transmitter, Fig. 65, and receiving equipment, Fig. 66. The rating of the previous outfit was 50 watts. The progress already made in this new method of telephoning is indicated by the fact that it has already been adopted for 70 transmission lines with an aggregate length of over 2000 miles.

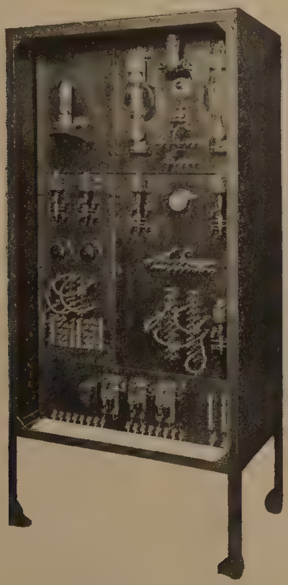


Fig. 65. 250-watt Carrier Current Transmitter

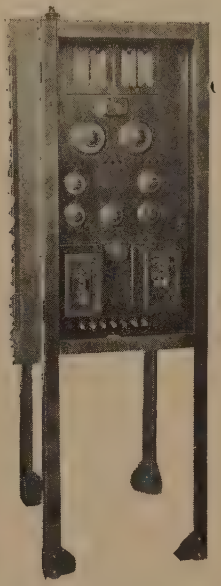


Fig. 66. 250-watt Carrier Current Receiver

The power required to accomplish carrier current telephony depends primarily upon the distance between communication points, upon certain particular transmission line conditions along this intervening distance, such as the number of tie-ins and transformers, and upon the extent of the transmission system. Obviously, if the energy generated by the carrier current transmitter must travel a longer distance, suffer reflection at certain points, or be distributed over a wider area, more energy will be required for a given communication. As the result of continued research work, considerable advance was made in determining how most effectively to bridge gaps and transformers by means of two capacity couplings. Selective ringing apparatus was also provided, which permits the calling of any one station on a system without calling the others.

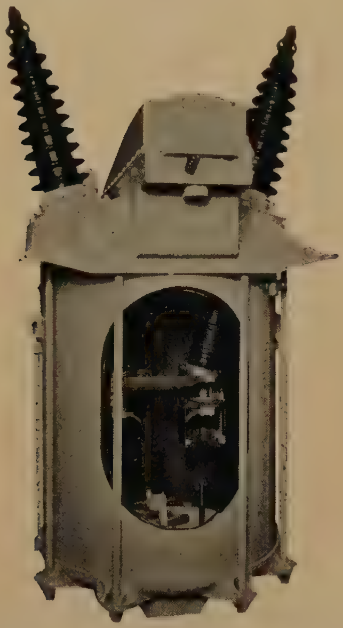


Fig. 67. Oil Circuit Breaker with Tank Cut Away to Show Location of Explosion Chambers

Portable equipments were also placed under construction so that communication with headquarters could be maintained by carrier current while inspection or repair work was in progress at distant points on a transmission line.

SWITCHING APPARATUS

The developments in switching apparatus consisted largely in the improvement of existing designs rather than in bringing out strictly new types of apparatus. Both horizontal and vertical isolated phase arrangements were worked out in detail for several important installations and the application of breakers to removable trucks was extended to include motor-operated breakers with separating chambers.

Adoption of the round tank type of high interrupting capacity oil circuit breakers was extended until there is now available a practically complete line of these breakers for use in systems having potentials of from 7500 to 220,000 volts.

An interesting and important feature of large tank type breakers is the use of the explosion chamber which very materially helps the operation of the breaker. The strong metal vessel is enclosed in an insulating housing and is capable of withstanding unusually high pressures. The accepted advantage of this feature, on large breakers, is that the stress on the outer tank, Fig. 67, when the circuit is interrupting, is greatly reduced because the chamber pressure is gradually released to the outer tank. Thus the reduction in pressure in the outer tank means either a greater factor of safety for the tank or a greatly increased interrupting capacity for the same pressure in the outer tank.

The explosion chamber, Fig. 68, has proved to be a valuable addition to the mechanical operation of contacts, of great assistance in extinguishing the arc quickly and is probably one of the most important developments in oil circuit breaker manufacture.

Medium capacity oil circuit breakers were improved in design so that a complete line is now available for truck mounting with mounting frames so arranged that the long side of the tank is at right angles to the mounting surface rather than parallel with it, as has been the custom in the past for breakers of this class.

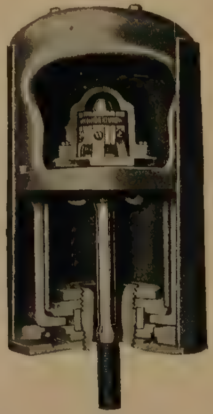


Fig. 68. Details of Construction of Explosion Chamber for Oil Circuit Breakers

Extraordinary testing facilities were provided and newly produced apparatus was tried out and put on a manufacturing basis only after the construction of various samples, the carrying out of many tests and exhaustive investigation of test data. Even though test data may indicate that devices as originally designed are satisfactory, further careful tests are always carried out with tool made devices chosen at random from the first lot built in regular production. Oftentimes apparently insignificant details materially affect the performance of the tool made samples and further changes are necessitated. When the final tests have been passed successfully, there is every assurance that the breakers, or other devices, will give dependable and long enduring service in the field since the test conditions are much more severe than those encountered in a large majority of installations.

When the cost of ground per square foot is high, the building for a large power station in the thickly settled, well-developed section of a big city must make up in height what it lacks in length and width and this condition often has a direct effect on the arrangement of the station equipment.

An example of unusual design, rendered necessary by the high cost of real estate, consists of an equipment of 28,000-volt, triple-pole, oil circuit breakers which, including the control and operating mechanism, occupy a space just five ft. square, but rise to a height of 58 ft. 6 in. They are intended for the Hudson Avenue Generating Station of the Brooklyn Edison Company. The departure from the regular arrangement is found in the location and the control, rather than in the breaker units themselves for these are of standard tank type construction. They are placed one above the other, one phase to a floor, with the operating mechanism on the fourth floor.

The main frame of each breaker unit, Fig. 69, rests upon a steel rim which in turn rests upon a movable cradle. Each cradle, geared on two sides to jack-screws, can be raised or lowered. Long rods, with universal joints, reaching from the operating mechanism to the floor of the lower breaker unit, a distance of about 55 ft., connect the jack-screws. With a 2½-h.p. motor on the fourth floor, geared with worm and worm-wheel to a shaft which is bevel-geared to the rods, all three cradles can be raised or lowered at the same time.

Three positions of the breaker unit were provided for: An operating position, a disconnected position, and an inspection position. In the first, or operating position, the terminals of the breaker unit, or more properly, the self-aligning contacts, are held tight into similar contacts suspended from the ceiling above.

By the use of an ingenious clamping mechanism, the breaker is held rigid in this position and cannot, through any mistake, be lowered. A third rod, hung from the solenoid, located on the fourth floor, operates all three units simultaneously.

The breaker can be operated only when the clamping mechanism is closed, avoiding all danger of closing the breaker while in an improper position. On the other hand, the clamping mechanism can be released only when the breaker is open, so that it would be impossible to lower the breaker units while they were carrying current.

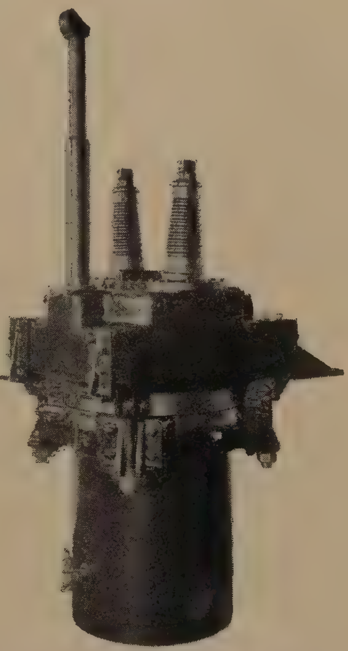


Fig. 69. Single-pole Unit of 600-ampere, 28,000-volt, Triple-pole Oil Circuit Breaker

After the breaker has been opened and the clamping mechanism released, a pressure on a push button marked "Lower Breaker" will start the motor, and the jack-screws, acting in unison, will lower each breaker unit to a point 15 in. below the operating position, and stop automatically.

This is the disconnected position and the breaker is removed completely from the line. A novel feature of this arrangement lies in the fact that the ability to place the breaker units in this position makes the use of the regular disconnecting switches unnecessary, the breaker forming its own disconnecting switch.

In the third, or inspection position, the three tanks are lowered simultaneously and held below the breaker frame, leaving the contacts of each unit open for inspection.

Four buttons control all the movements of the breaker units. Two are for lowering and raising the breaker units between the operating and disconnected positions; and two are for lowering and raising the tanks.

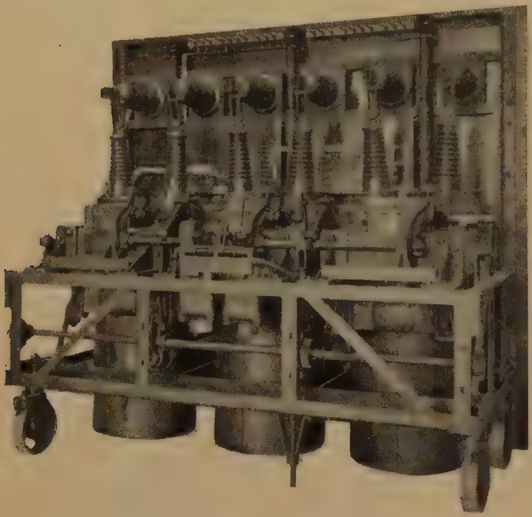


Fig. 70. Truck-mounted Three-phase Oil Circuit Breaker Rated 600 Amperes, 37,000 Volts

By the use of a truck with a platform which can be raised and lowered, some of the advantages of the convenient truck-type panel switchboard may be obtained. The truck is rolled underneath the unit to be removed, the platform raised, and all three breaker units lowered. Two of the breaker units will come to rest at the disconnected position. The third, which is to be removed, will come to rest on the platform a little before the other two units. The front of the cradle is unfastened, and the breaker unit rolled out of the frame.

After removing the unit, the truck platform can be lowered so that truck and load may be rolled through the doorways. The unit can be removed by two men in 15 minutes after it is lowered to the truck.

A new design of oil circuit breaker, Fig. 70, for indoor installation (for opening a three-phase circuit) is mounted on one truck, together with its mechanism for solenoid operation. It is rated 37,000 volts, 600 amperes; the highest voltage yet used with a breaker for truck operation.

With the removable truck withdrawn from its housing a shutter encloses the live buses on the housing, eliminating the danger of a person coming in contact with the high voltage parts and protection for the apparatus is provided so that the truck cannot be withdrawn unless the breaker is open. Also the breaker cannot be operated unless the truck is either wholly out of its housing (contacts disconnected) or fully run into its housing (contacts made). This prevents

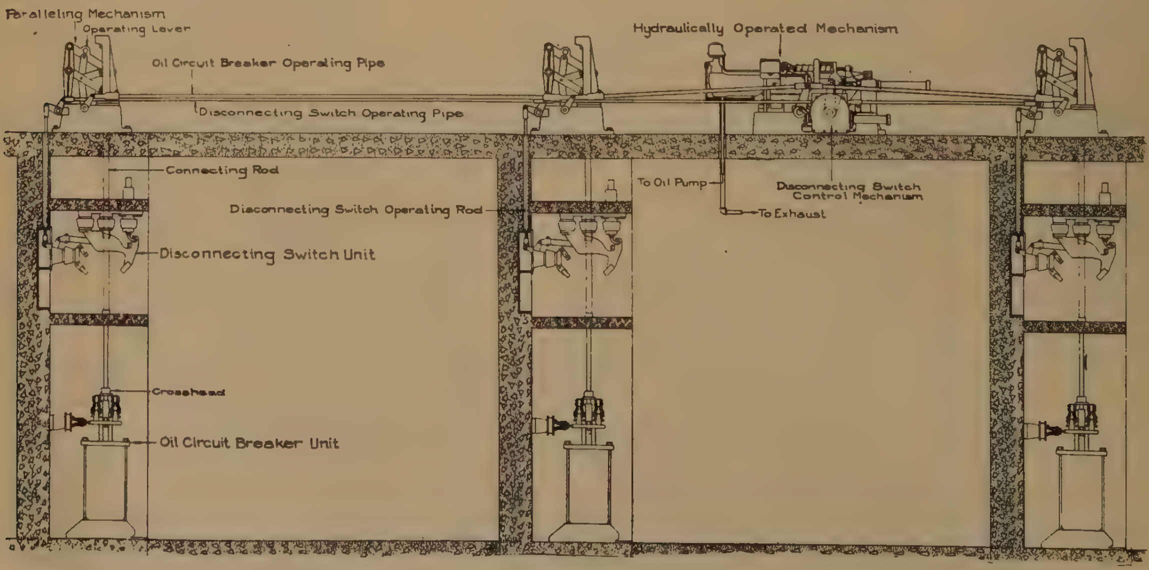

Paralleling Mechanism
Operating Lever
Oil Circuit Breaker Operating Pipe
Disconnecting Switch Operating Pipe
Hydraulically Operated Mechanism
Connecting Rod
Disconnecting Switch Operating Rod
Disconnecting Switch Unit
To Oil Pump
To Exhaust
Disconnecting Switch Control Mechanism
Crosshead
Oil Circuit Breaker Unit

Fig. 71. Arrangement of Units of Hydraulically Operated Oil Circuit Breaker

a possible injury to the disconnecting device contacts through their being accidentally used to break the current instead of the breaker contacts.

The truck panel is of the well known "dead front" type with the necessary control relays, overload relays, etc., mounted back of the panel; access to them being obtained through hinged doors in the steel panel front.

A novel feature of this truck mounted oil circuit breaker installation is the ability of the attendant to test the high voltage buses for potential. Upon closing a small switch by means of a pull-button on the right side of the housing two glow lamps (placed at either end of the front of the housing superstructure) glow when the buses are "alive."

A very ingenious hydraulically operated mechanism, Fig. 71, was provided to operate certain horizontal, isolated phase, dead pot oil circuit breakers for the Commonwealth Edison Company. The pots are oil tight and electrically dead and each pole, consisting of two pots with contacts, is mounted on a truck so that it can be removed from the isolating cell for inspection and repair and a spare unit inserted in its place.

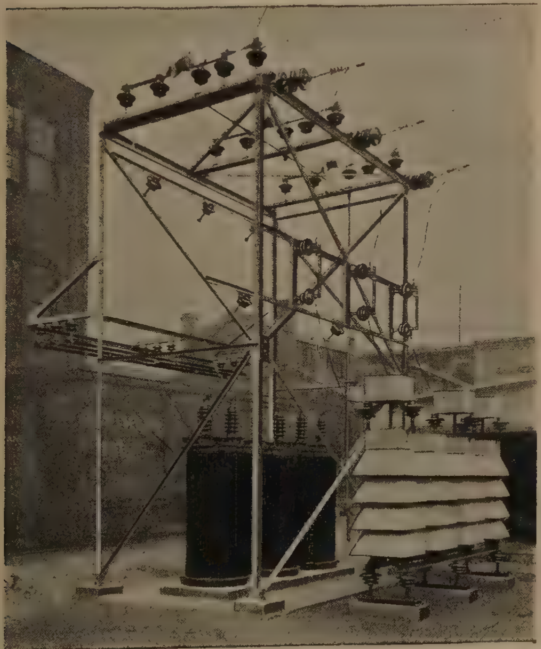


Fig. 72. Standardized Equipment for Outdoor Substations

The operating mechanism consists essentially of a motor, an oil pump, oil chambers and operating springs. In addition there are two disconnecting switch control mechanisms for operating, automatically and manually, either single-pole, single-throw, or single-pole double-throw selector disconnecting switches.

Control for the apparatus is centered at a three-button control switch which indicates by red, green, and white lights, the position of the breaker contacts at any time. By operating one control switch, oil fed from a motor-operated pump is forced into the valve and piston mechanism which causes the piston to move and charge the operating springs and at the same time closes the disconnecting switches.

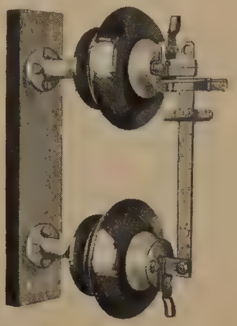


Fig. 73. 37,000-volt, 300-ampere Outdoor Disconnecting Switch

To close the breaker, a second control switch is closed, thereby releasing the latch on the mechanism crosshead. The closing springs at this time dissipate their energy in forcing the crosshead to close the oil circuit breaker. By closing a third control switch, the latch on the opening trip toggle is released and the oil circuit breaker is opened.

Ten seconds after the oil circuit breaker opens, the disconnecting switches automatically open by the operation of the disconnecting switch opening spring which is then released.

Development work on outdoor switching equipments was continued and they are now available, Fig. 72, for circuits up to 66,000 volts as completely standardized units. Equipment for use up to 220,000 volts is also available but has not yet been standardized. Several improvements were added to the tower structure making it mechanically stronger.

The adoption of a new type of pin insulator for outdoor work resulted in the design of a new disconnecting switch, Fig. 73, with insulators placed at an angle of 90 deg. rather than of 45 deg. as in previous practice.

Disconnecting switches for circuits of from 25,000 to 220,000 volts, Fig. 74, were equipped with insulators that are interchangeable with those of the same voltage rating furnished on fusible cutouts, and other outdoor disconnecting switches, choke coils, oxide film arresters, and bus wire supports. Only one type of spare insulators need, therefore, be carried in stock to replace high voltage insulators on outdoor equipment.

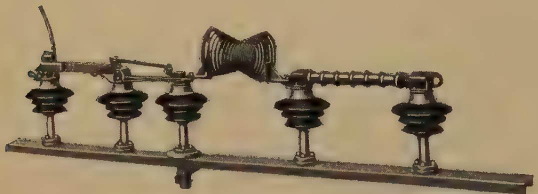


Fig. 74. Single-pole Unit of High-tension Disconnecting Switch with Choke Coil

A new breaker mounted on a removable truck element, Fig. 75, was so designed that with the truck element in place for operation all live parts are completely enclosed while with the truck removed all its parts are absolutely dead electrically.

The solenoids of each phase are interlocked so that the breaker units of all phases will open together and close together and in order to pull out the truck of any one phase all the breaker units of the circuits must open or the truck cannot be pulled out.

Each unit is equipped with an interlock for locking open the breaker which projects through the front of the panel and may be secured by a padlock so that the operator may work on the circuit controlled without any chance of an assistant throwing in the breaker. Interlocks are also provided between each single-pole unit and the floor so that the truck cannot be rolled out unless the breaker is in the open position. This eliminates the possibility of an operator rolling out the truck with the breaker closed and thereby breaking the arc in the air. By unbolting the breaker covers, the breaker mechanism can be lifted out of the tanks and truck as a complete unit for adjustment or inspection.

This oil circuit breaker is available for either automatic or non-automatic operation, solenoid operated, in capacities of 7500 volts, 600 amperes and can be arranged for single-throw, single-, double-, triple-, and four-pole operation as well as for 7500 volts, 1600 amperes capacity, single-throw, single-, double-, triple-, and four-pole operation. The interrupting capacity is 13,350 amperes at 7500 volts.

An extension in the line of moderate rating breakers consists of a heavily constructed standard unit, Fig. 76, with an interrupting capacity of 4500 amperes at 15,000 volts. It is available in two ratings, 7500 volts, 1200 amperes and 15,000 volts, 600 amperes, either manually or solenoid operated.

This breaker can be mounted on pipe framework, in cells or on trucks; when mounted on trucks it has been found convenient in order to maintain a straight and clear run of connection bars, to turn the breaker units through an angle of 90 deg. to the conventional mounting, that is, with the oil tanks turned at right angles rather than parallel to the mounting surface. A different arrangement of operating mechanism is used under these conditions.

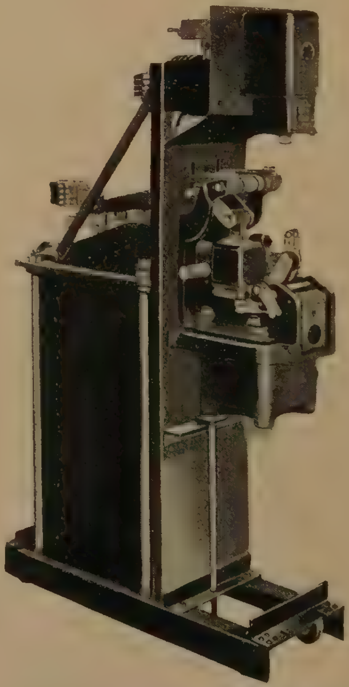


Fig. 75. 600-ampere, 7500-volt Truck-mounted Oil Circuit Breaker Unit with Special Interlocking and Safety Features

The number of solenoids required for operating large capacity alternating-current, triple-pole air circuit breakers was reduced from three to two. In the previous type of construction, the breaker-unit of each phase was operated by an independent solenoid, but by connecting each operating rod to a countershaft, and operating the countershaft by two solenoids, the elimination of one solenoid was rendered possible.

In a large power station, a too-narrow stairway stood at the end of a long switchboard and in order to remodel the stairway, a shortening of the switchboard was necessary; an expedient rendered possible only by the use of very narrow circuit breakers.

A special air circuit breaker was developed for such conditions with vertical dimensions practically the same as those of the older type, and it can be mounted on the same studs. The width over all, however, was reduced from $6\frac{9}{16}$ in. to 4 in., permitting the breakers to be located on 6-in. centers.

These new breakers, Fig. 77, are solenoid operated and are directly connected in the busbars. They are non-automatic, used on 250-volt, 2400-ampere circuits and are made up as complete units which may be secured into place on the feeder bars from the front, by tightening the nuts on three studs at each side of the breaker. The upper contact block is insulated from the other parts, and the busbars to which the breakers are connected are run horizontally back of, and are supported by, a suitable iron framework. The framework, or feeder bar, on which the breakers are mounted is supported by the insulated studs at the top and bottom.

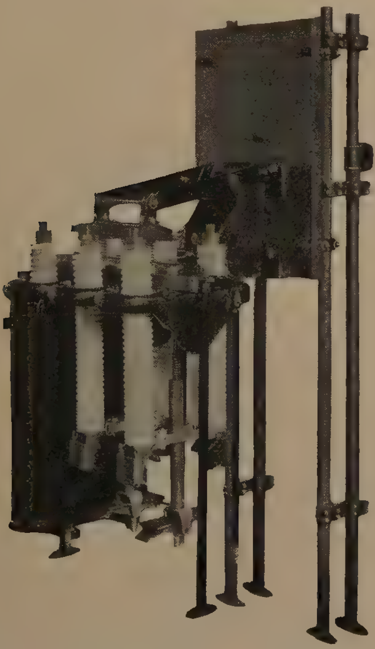


Fig. 76. 600-ampere, 15,000-volt Oil Circuit Breaker in Open Position with Two Oil Tanks Removed

An overload air circuit breaker somewhat similar in design to the standard solenoid-operated breaker is equipped with a closing solenoid coil which acts also as a holding-in coil. The new breakers will trip on falling voltage, or when the holding-in coil circuit is opened, which may be accomplished either with a special control switch, or by a circuit opening switch actuated by the overload armature on the breaker.

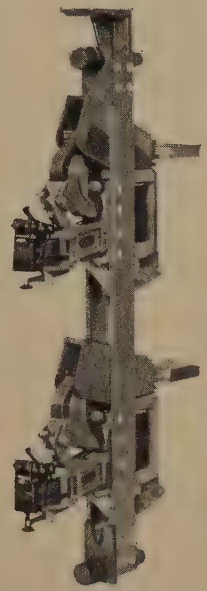


Fig. 77. Solenoid-operated Air Circuit Breaker, 2400 Amperes, 250 Volts, Direct Current

High conductivity copper castings were produced free from blow and oxide holes as well as high strength aluminum alloys which have enabled the designer to replace successfully brasses and malleable iron for some classes of construction.

Relays

A new type of hinged armature relay, Fig. 78, was designed to function as a direct current auxiliary relay and is of simple construction and very reliable in operation.

It has two coils mounted on parallel pole pieces fastened to the same steel base, which makes a U-shaped magnetic structure. The armature bridges the open end of the U, and since it is loosely pivoted at the bottom, it is free to adjust itself to the position of the pole faces. The two-coil construction gives an unusually good margin between minimum operating value and continuous current carrying capacity. The insulation is all of moulded parts and all four contact tips are of silver.

A new type of induction overload relay has as an outstanding feature a target which is "built in" the relay and indicates when the relay has functioned to trip the particular circuit which it controls. The contacts are definitely geared to the shaft. The holding coil of these relays, therefore, does double duty in that it holds the contacts closed after they have once been closed in any cycle of operation and also operates the target. This relay can also be provided for undervoltage protection.

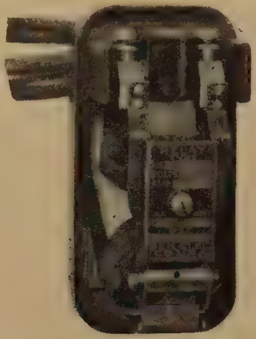


Fig. 78. Instantaneous Auxiliary Direct-current Relay with Contacts for Closing One Circuit

The triple-pole induction relay was provided with a current indicator, Fig. 79, built on the inclined vane principle. It is built as a triple-pole relay only.

The indicator is connected in series with the relay coil but the current indicator is not consolidated with the other elements except that it is mounted in the same case. As it is an independent element there is no mechanical or magnetic interference. Another point of interest is that the scale is in accordance with the current transformer capacity, that is, it is not affected by a change of relay setting. Another important feature of this triple-pole relay is that it requires exceedingly small panel space.

Contacts for plunger relays were developed, Fig. 80, capable of opening two separate circuits and at the same time keeping these circuits electrically separated. The contact head may be assembled so as to make the contacts either circuit opening or circuit closing. The relay so equipped may be automatically reset to its normal position or hand reset and may be provided with either instantaneous or time features.

A special overload relay to be used in connection with balanced power protection of two parallel but dissimilar lines, Fig. 81, is somewhat similar to the former type of induction overload relays which has been largely used for general overload protection but is provided with a restraining element which tends to rotate the disk to hold the contacts open. The different characteristics of the two lines, Fig. 82, causes the currents in them to be unequal in magnitude and out of phase. This results in a current in the operating coil of the relay which equals their vector difference and which is a constant percentage of the total current carried by the two lines. The circulating current of the cross-connected current transformers passes through the coil of the restraining element which

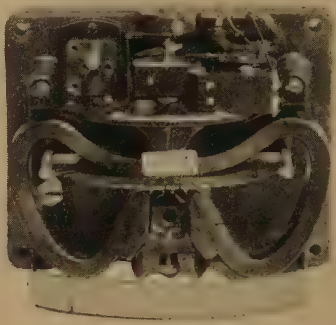


Fig. 79. One Unit of a Triple-pole Relay Equipped with a Current Indicator

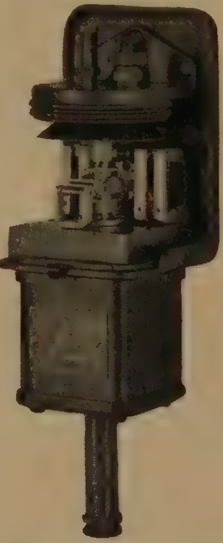


Fig. 80. Plunger Type Relay Equipped with Universal Contact Head

compensates for the torque produced by the unbalanced differential current passing continually through the operating coil.

An induction type balanced relay is now used as a frequency relay, Fig. 83, being convertible from overfrequency to underfrequency by the rotation of the pole pieces of the driving magnets to change the direction of torque.

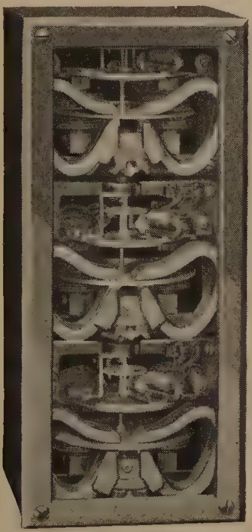


Fig. 81. Balanced Power Protection Overload Induction Relay

The disk is acted upon by two magnets, Fig. 84, which tend to produce rotation in opposite directions. The coil on one of these magnets is connected across the source whose frequency is to control the relay and the coil of the other magnet is connected in series with a condenser across the same source. As the frequency changes, the currents in the two coils change oppositely because one coil circuit is highly inductive while capacity predominates in the other coil. The increased current in one is accompanied by a decrease in the other and causes the disk to rotate and control the contacts.

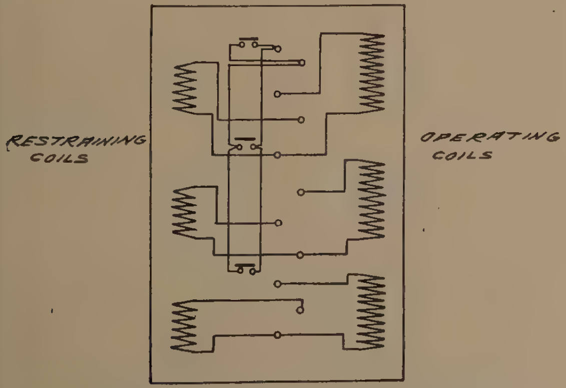


Fig. 82. Internal Connections of Balanced Current Relay

Fig. 83. Induction Type Balanced Relay Used as a Frequency Relay

LIGHTING

The volume of sales of incandescent lamps serves as a reasonably accurate measure of the expansion of the lighting business. It is estimated that about 225,000,000 large tungsten filament lamps were sold in the United States during the year 1923. This is nearly 11 per cent increase over 1922, and exceeds any previous year. The figures do not include the sale of miniature lamps, which are used in large numbers for automobiles, flashlights, etc. The sales of carbon lamps are also excluded, since they have shrunk to an insignificant number.

Since the advent of the Mazda C lamp with its larger sizes and greater efficiency, the simple numerical measure has ceased to show the expansion as regards wattage consumed or light supplied. This is indicated by the following tabular comparison of the lamps

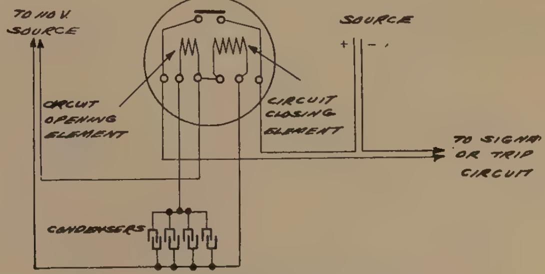


Fig. 84. Internal Connections of Frequency Relay

sold in 1923 with those of 1907, when the tungsten filament lamps first appeared on the market.

TABLE II

	1907	1923	Per Cent Increase
Total number of lamps sold	65,500,000	225,000,000	246
Aggregate wattage of lamps sold	3,365,500,000	12,375,000,000	267
Aggregate lumens of lamps sold	11,430,000,000	150,750,000,000	1215

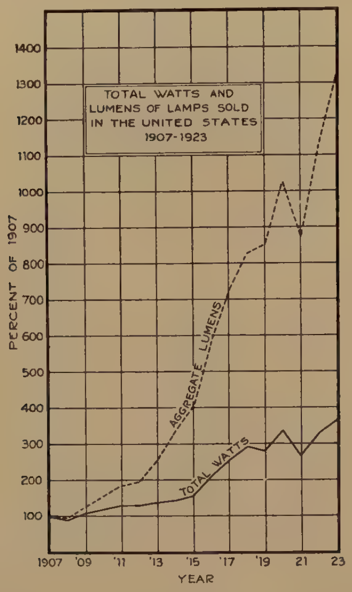


Fig. 85. Aggregate Wattage and Lumens of Incandescent Lamps Sold (Excluding Miniature Lamps)

A comparison of the lamps sold in 1923 with those of 1922 shows an increase of 11¼ per cent in aggregate wattage and 17½ per cent in aggregate lumens.

The chart, Fig. 85, shows the aggregate wattage and lumens for the lamps sold during each of the years from 1907 to 1923 inclusive, in per cent of the 1907 figures. The wattage curve may also serve to represent the relative number of lamps, which curve is omitted because it follows the wattage curve so closely that the two could not be differentiated at the scale used.

It will be noted that the 1923 wattage is 3⅔ that of 1907, and the 1923 lumens over 13 times that of 1907. The number of lamps sold in 1923 is correspondingly 3½ times that of 1907. The average wattage of incandescent lamps during this period varied from about 53 in 1907 down to about 47 in 1913, and up to about 55 in 1923.

These figures provide a measure of illustrating the influence of lamp improvement in reducing the cost per unit of light. It is estimated that the lamps sold in 1923 will have consumed $620,000,000 worth of electricity. If the public in 1907 had used the same amount of light as they did in 1923, it would have cost, with the poorer efficiency lamps then employed, about two and one quarter billion dollars. Furthermore, a greater number of lamps would have been required to produce this amount of light and the cost of these lamps would have been considerably more than the tungsten filament lamps bought in 1923. The cost of the electricity actually used for lighting in 1907 is estimated to have been about $175,000,000, so that the influence of lamp improvement since 1907 has been to slightly more than triple the amount of electricity used for which over 13 times the amount of light was obtained.

This great reduction in cost per unit of light, almost all of which has been due to improvement in lamp efficiency, there having been a slight reduction in the general average rate at which all current for lighting purposes is sold, is undoubtedly the major reason for the increasing expenditure for electricity and the increasing amount of light being used. This remarkably rapid extension of electric lighting has surely contributed an even larger economic value through the speeding up of industrial processes, the stimulation of commercial activity and the influence on welfare and safety, resulting from the greater abundance of artificial illumination.

The construction of the more important types and sizes of tungsten lamps was changed to eliminate the tip on the bulb, thereby reducing liability to breakage and improving the appearance of the lamps. The change necessitated extensive changes in certain processes of lamp manufacture, requiring new machinery and apparatus.

Tipless lamps have the air and moisture exhausted through a tube inside the stem which also serves for the entrance of gas in the gas-filled lamps. When the tube is sealed off the tip is covered and protected by the lamp base.

A new method of making the popular sizes of lamps was adopted by some of the lamp manufacturers. Formerly, individual machines and departments performed particular processes, the lamps or parts being transported from one location to another, between steps of manufacture. This required considerable floor space for storing and handling. With the new method of manufacture, the various parts of a lamp are made and assembled on a single "unit" machine.

In the sign lamp, the shape of the filament, Fig. 86, was changed to a coiled ring form which makes the filament mechanically stronger and increases the end-on candle-power of the lamps. As used in signs, the spots of light appear larger, and when properly spaced, the appearance is more nearly a continuous line of light than that secured with previous types.

The healthy growth of the miniature lamp business during the year is indicated by the increase in sales to about 110,000,000 as compared with 85,000,000 for 1922, that is, an increase of about 30 per cent. Of the lamps sold in 1923, about 20 per cent were for flashlight service, 12½ per cent for Christmas tree decoration, and 65 per cent for automobile service, the remaining 2½ per cent being of miscellaneous types.

In response to the demand for mechanical accuracy, especially in connection with motor vehicle headlights, several automobile headlight lamps were put in production, with the maximum variation limits of filament position in any direction reduced to $\frac{3}{64}$ in.; the former specifications permitting a variation $\frac{3}{32}$ in. either way in light center length, and $\frac{5}{64}$ in. in axial alignment. The lamps so affected are the 6–8 volt, 21 candle-power and the 12–16 volt, 21 candle-power, each with either single or double contact bases, also the 6–8 volt double filament, 21–2 candle-power Ford headlight lamp, which is made only with the double contact base. Thus the "precision" lamps are now available in five different styles.

In the field of railway signal service, there was considerable increase in the application of Mazda miniature lamps operated from primary batteries. Not only were they employed for night signalling, but to a rapidly increasing extent in the so-called "daylight color signal." In this application, the moving semaphore arm is replaced by three lamps, fitted respectively with red, green and yellow lenses. Track circuit relays cause the proper color to light up on the approach of a train, and to go out after the train has passed.

A year's service test in twelve of the most important lighthouse districts has proved miniature Mazda lamps, operated by batteries, to be more effective and economical than the gas and oil lamps previously used in post and marker lanterns for minor lights. Plans are under way for a considerable extension of the use of incandescent lamps in lighthouse service.

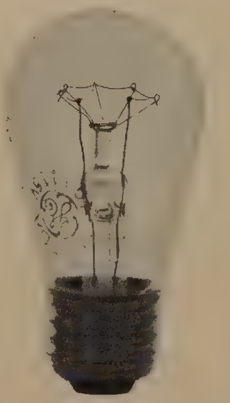


Fig. 86. New Type of Sign Lamp Showing the Coiled Ring Filament

Some experimental work was done in applying miniature Mazda lamps to routing beacons for night flying, the problem being more or less similar to that of the lighthouse service. It is probable that, as night flying increases, such lamps will play no small part in the marking of routes and so contributing to the safety of this means of transportation.

An interesting development consisted of a small motion picture projector for home use, utilizing a 14-volt, 4-ampere concentrated filament Mazda lamp for the light source. A convenient camera was also produced, and this combination, together with a prompt film development service, so facilitates the making and projection of motion pictures for home use, as to present an opportunity of creating a similar popularity for amateur motion pictures as now exists for still pictures.

Automobile headlighting is gradually improving under the stimulus of lighting regulations and as the dimensions of incandescent lamps for this service can be more accurately controlled when corresponding improvements are made in the focusing equipments of the lanterns, a further advance may reasonably be expected. However, there is no improvement in sight which will entirely eliminate headlight glare, and the illuminating engineers who have studied the problem most carefully, seem to be in agreement that the solution, so far as heavily traveled roads are concerned, will be reached only through the installation of highway lighting. This, of course, will not do away with the necessity of headlights and the desirability of making all possible improvement in the control of headlighting.

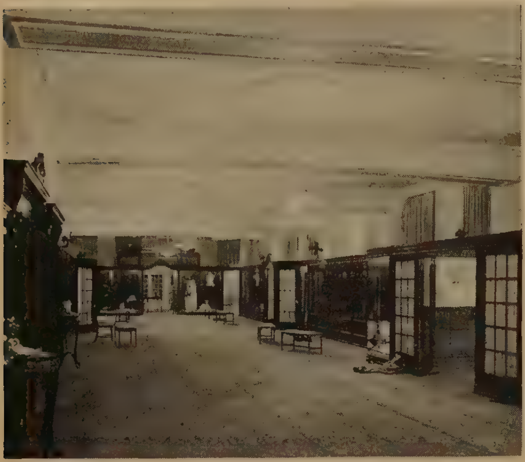


Fig. 87. An Example of the Use of Light as a Decorative Medium. The luminaires are in conformity with the architectural treatment and produce an even toned illumination

Incandescent lamps are finding additional applications about the automobile to enhance the safety and comfort of night travel. A real step forward is the movement led by the State of Massachusetts, to require rear lanterns to be so arranged as effectively to illuminate the license plates. As a result of this activity, practically all equipment now manufactured is accomplishing this result, whereas a year ago, an investigation found only one out of about 400 tail lights which properly illuminated the number plate.

While the need for more and better lighting in homes has been obvious to illuminating engineers, the magnitude of the problem and the demand for individuality has made it difficult to advance the practice. During the year unusual progress was made in improving the lighting of kitchens, in connection with certain enclosing luminaires. The results proved so successful that campaigns are being undertaken throughout the country, which will serve to teach the possibilities of lighting in other parts of the home where standardization is not practicable.

The store lighting activities in Chicago, which were reported at the recent National Electric Light Association's convention, pointed out the possibilities of raising the standards to the advantage of both the storekeepers and the industry. Lighting units selected with reference to engineering characteristics were aggressively promoted by the lighting company through commercial channels and as a result, the Chicago stores spent $800,000 (or 45 per cent) more for electricity than in any preceding year. The previous survey had classified 70 per cent of the Chicago stores as poorly lighted, although presumably as well lighted as those in other cities. All the revised installations, Fig. 87, were at a level of at least 10-ft. candles and were otherwise in accordance with good practice.

While the year did not stand out as one of special activity in industrial lighting, it is interesting to note that the practice in new and revised installations, Fig. 88, was of a high standard. Lighting from large overhead units is now thoroughly established, but it is recognized that there are processes where it is advantageous to supplement general illumination with local lighting. A need for better local lighting reflectors for this purpose has been felt, and through the co-operation of engineers, some improved designs were developed.

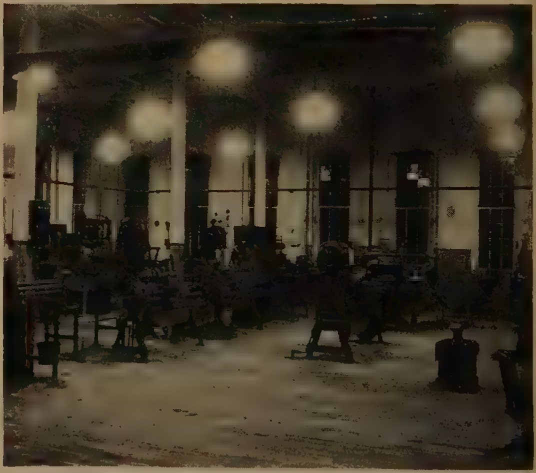


Fig. 88. Machine Shop Illuminated with 200-watt Mazda C Lamps in Glassteel Diffusers on Approximately 10-foot Centers

An investigation of light losses from various kinds of dirt accumulating on reflecting and transmitting surfaces gave data which confirmed previous conclusions regarding the need of systematic cleaning of lighting equipment.

A federal investigation indicated the need of more and better illumination in post offices, not only from the standpoint of the employees' welfare, but also to increase the speed and accuracy of work, such as the sorting of mail. Recommendations made call for improved equipment and about double the illumination previously employed.

In the past, art gallery lighting practice has been principally concerned with public galleries. During the year, two very notable installations were made in private galleries, devoted to the sale of paintings and other objects of art. This introduced new economic factors, and after very careful study, some new and interesting methods were developed. It was considered fully as important to provide a suitable supplement to fading daylight as to furnish night lighting. In one instance, light was projected through skylights, Fig. 89, while in the other, new designs of reflecting equipment were cleverly incorporated below the skylights, without introducing inartistic equipment. Reported tests show remarkably satisfactory distribution of light and absence of reflected images.

An English investigation brought out the fact that incandescent light is less liable to produce fading of valuable fabrics and other exhibits than is daylight.

The influence of artificial light on plant growth has been studied by horticulturists for a number of years and the past year witnessed the compilation of results of several very extensive investigations. These seem to indicate the economic practicability of supplementing daylight with incandescent lighting under certain favorable conditions, for example, to bring flowers to bloom for Easter and Christmas. The indications are that such lighting will shortly find a definite place in the control of plant growth.

In the past, it has been usual to take daylight for granted, and but little data has been available as to its variations. Recent investigations, however, have begun to provide systematic data, which will be useful, not only in improving building design, but also in coordinating artificial lighting with daylight.

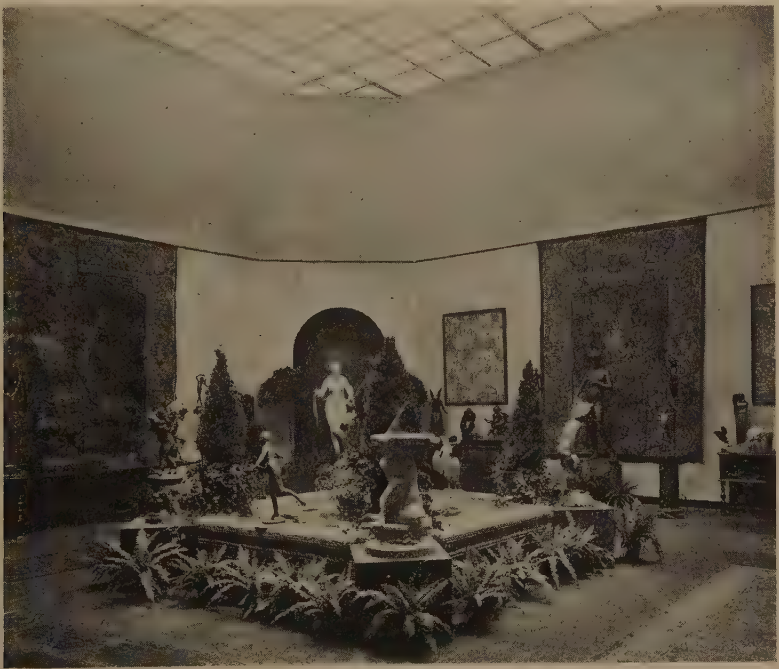


Fig. 89. Art Display Room Lighted by Projector Type Units from Above the Sky Window

Street Lighting

The year was notable in many respects in street lighting history. Traffic has continued to multiply so rapidly that the present systems of lighting on thoroughfares in most cases are inadequate and in an effort to correct this condition and relieve night congestion of traffic, many cities have realized the necessity of revamping their entire street lighting systems.

Prominent among these are St. Louis, where eight million dollars was voted for street lighting, and where in the next five years, at least 45,000 ornamental lighting standards will be installed; the District of Columbia is considering the installation of a complete new system involving between 20,000 and 30,000 new ornamental units at an expense of over four million dollars to the central station and to the district; the city of Columbus, Ohio, is experimenting with various types of new street lighting systems before applying for a bond issue to replace their present equipment. These are the most prominent examples among the larger cities which are considering the wholesale replacement of their present street lighting facilities, but there are numerous other cases where similar improvements are under way including the creation of special lighting districts, and the extension and strengthening of existing systems.

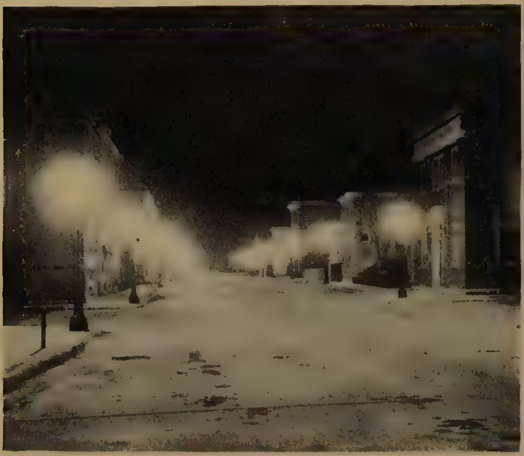


Fig. 90. Ornamental Street Lighting Units Mounted on Flemish Design Standards

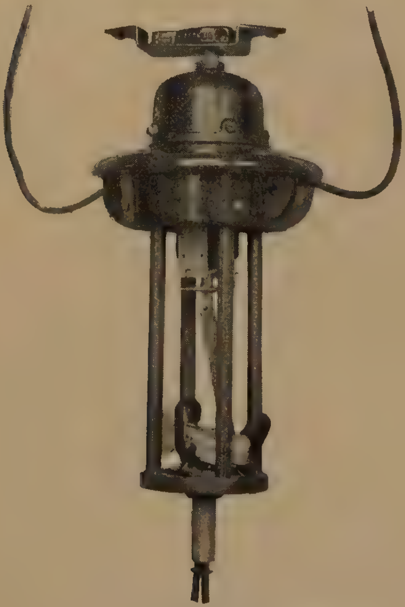


Fig. 91. Mercury Switch for Series and Multiple Operation

In all of these cities there was a noticeable trend toward high intensity lighting in the business districts. The effect of such systems, Fig. 90, on the character of modern street lighting can be readily appreciated by the increase in the light intensity on some of the streets recently equipped as indicated by the items in Table III.

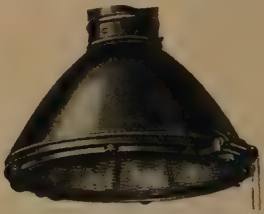


Fig. 92. Fixture with Projector Type Reflector for Illuminating Traffic Officer

TABLE III

INCREASES IN INTENSITY OF ILLUMINATION AS COMPARED WITH SUPERSEDED SYSTEMS

Market Street, Lynn	18 times
Broadway, Saratoga	15 times
Market Street, San Francisco	15 times
Triangle District, San Francisco	12 times
South State Street, Chicago	11 times
Main Street, State Street, and Broadway, Salt Lake City	8 times
Broadway, Los Angeles	6 times

In addition to the ornamental high intensity systems for business districts, there was a definite trend toward ornamental lighting of higher intensities in other parts of the city. In Syracuse, New York, for instance, where the business district will be lighted by ornamental luminous arc lamps, the entire residential districts will be lighted by lanterns on ornamental standards.

Most of these cities are planning their new systems in a most comprehensive and intelligent way. They are first analyzing their requirements, not only for the present but over a period of years. Lansing, Michigan, for example, determined upon a lighting plan, and selected lighting units and orna-

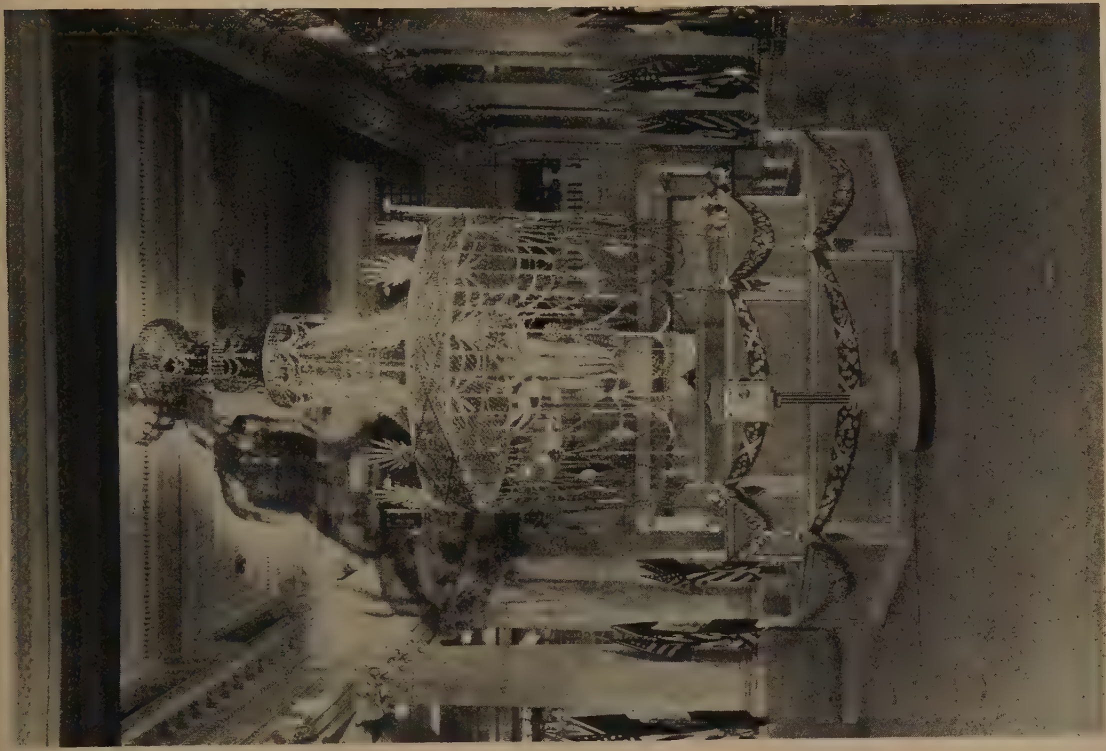


Fig. 94. Jeweled Fountain at Grand Central Palace Illuminated in Colors

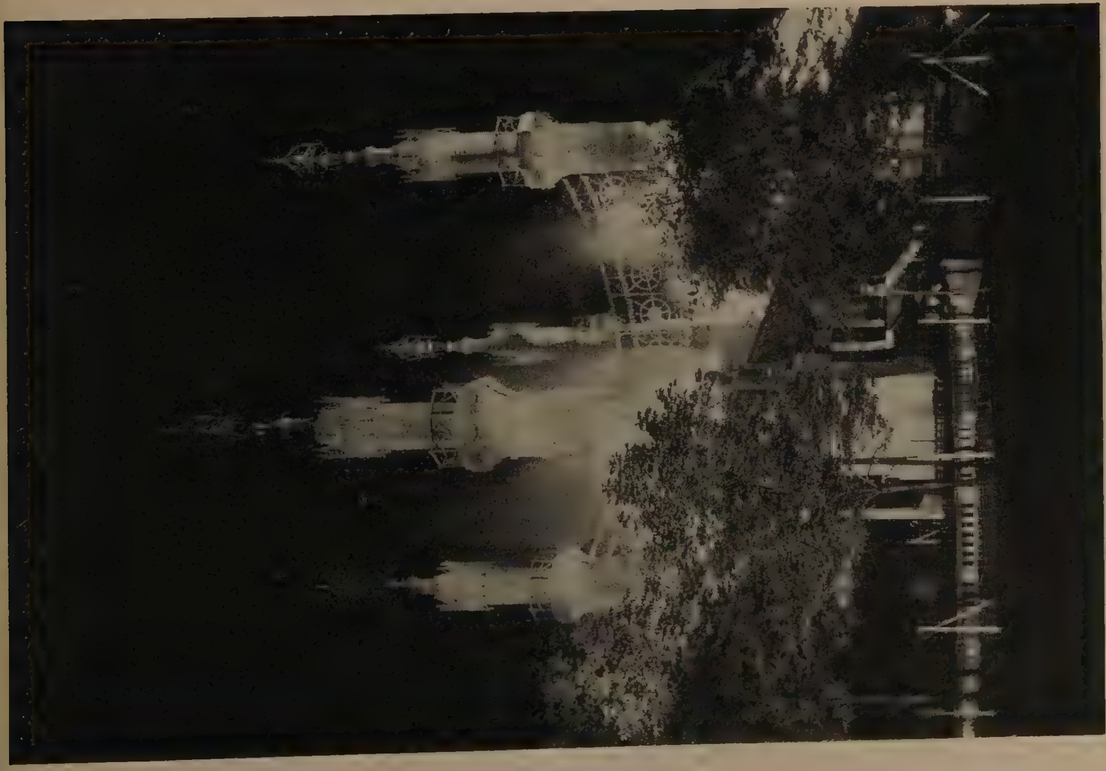


Fig. 93. Four Oriental Jeweled Towers Illuminated by Searchlights

mental standards of various sizes and intensities for different parts of the city, but all with the same architectural features. Some of the principal thoroughfares in residential districts have already received this treatment and probably this year the business district will be intensively lighted. Even if it requires a number of years to complete the program, there is always the assurance that there will be complete symmetry and harmony from an architectural and illuminating standpoint among all districts of the city.

For several years there has existed a demand for a relay that could be connected into a series circuit to operate a switch in a multiple circuit so that incandescent lamps on multiple circuits could be turned on and off in unison with the starting up and shutting down of an arc lamp circuit.

The device, Fig. 91, developed to meet these conditions consists of a coil that is connected into the series circuit while inside the coil is an armature which will open and close a mercury switch located below, as the current goes on and off. The mercury switch is connected in one side of the multiple circuit so that it opens and closes this circuit when the mercury is tipped from one side of the tube to the other.

The series coil is supported by a large porcelain insulator and the multiple circuit is kept a sufficient distance from the series circuit so that there is no danger of it coming in contact with it; the only connection between these two circuits being an insulating rod that tips the tube from one position to the other.

This tube is large enough to carry 25 amperes on a 110-volt circuit, or 15 amperes on a 220-volt circuit.

A special fixture was designed for hanging over the intersections of streets so as to illuminate the traffic officer. It is provided with a glass reflector, Fig. 92, that has been copper and silver plated, and is shaped so as to produce a concentrated beam of light equivalent to 5500 candle-power. Under normal conditions the traffic officer is rendered visible, in strong relief, for distances up to 1500 ft.

The adequate lighting of highways which was first rendered practicable in 1921 by the adoption of the Novalux highway lighting unit, was greatly extended and at the close of the year between 400 and 500 miles of our roads had been provided with this system of illumination.

The subject of railroad yard lighting aroused unusual interest during the year as the greater part of the revenue of our railroads is derived from the transportation of freight, and anything which tends to expedite its movement, with less chance of loss due to breakage, and with increased safety to the trainmen, is of great importance. The accepted method for the illumination of these yards is by means of floodlighting projectors placed on towers in various parts of the yard and considerable research work was undertaken to determine the best system of lighting with a minimum of glare, which is a very objectionable feature. A new floodlight, possessing several novel characteristics suitable for railroad work, was developed for this particular class of service.

Spectacular lighting was featured at many celebrations and exhibitions during the year. Probably the outstanding demonstration was the display at the Cincinnati Fall Festival. Four oriental towers, Fig. 93, each 90 ft. in height, were decorated with jewels and connected by curtains of these jewels. Fifty thousand jewels were lighted by 40 18-in. arc and 20 18-in. incandescent searchlights and this feature, together with the scintillating beams in the trees, illuminated banners and lanterns, made a fairyland of Washington Park.

Other noteworthy displays were the Fountain of Jewels, Fig. 94, at the celebration commemorating the Twenty-fifth Anniversary of the Founding of Greater New York at the Grand Central Palace, New York, and the illuminations in connection with the Seventeenth Annual Convention of the Illuminating Engineering Society at Lake George, N. Y. At the former, numerous water jets were illuminated from concealed colored sources and the colored beams from 20 18-in. arc searchlights played on a canopy of 30,000 jewels.

At Lake George the features were the colored illumination of the trees, hundreds of flaming torches, avenues of large colored canvas lanterns and a reproduction of one of the Scintillator, Fireworks and Steamworks displays which were so prominently featured at the Panama-Pacific Exposition.

Twenty-kilowatt Vacuum Tube Radio Telegraph Transmitter

By P. R. Fortin and C. A. Priest

Radio Engineering Department, General Electric Company

Popular interest has focused so intensively upon broadcasting and broadcasting reception that other important developments in the radio field have been overlooked to a considerable extent.

Trans-oceanic radio communication on a large scale is an accomplished fact, well known to the public; but the pioneer activities of the United Fruit Company in the field of radio communication have been carried forward to a successful conclusion with much less publicity than the magnitude of its achievements would seem to warrant.

Back in 1904, the United Fruit Company began the erection of the first radio station to be installed in Central America. Operation was begun in 1905, and this first experiment quickly proved its practical value to a business that handles so perishable a food product as the banana.

The United Fruit Company adopted, and has consistently followed, a policy which has kept it abreast—and often ahead of—the times in radio development; and, with the completion of the system now planned, it will have a chain of twenty-six land stations, affording adequate communication throughout the zone bordered by the southern boundaries of the United States and the northern boundaries of Colombia, South America.

The stations at Almirante, Panama, and Puerto Barrios (Guatemala) will be operated by the United Fruit Company; those at New Orleans (La.), Miami (Fla.), Tegucigalpa (Honduras), and Managua (Nicaragua), by the Tropical Radio Telegraph Company.

It is expected that all of these new transmitting sets will have been installed and put in operation by the summer of 1924, after which date it is confidently predicted that a certain popular song will lose its point.

—E. P. Edwards, Manager Radio Dept., G. E. Co.

For those who are not familiar with commercial radio apparatus, we call attention to the incompleteness of the term "transmitter" as applied to the aggregation of equipment described in the following article. More than a mere transmitter of radio signals as such, it contains the equipment necessary to convert ordinary commercial power to that different scale of values of voltage, amperage, and frequency which is applied to radio transmission. Because of this motor-generator function, it may be of interest to compare the radio equipment with a typical motor-generator set designed to convert energy to a form suitable for commercial light and power service.

The 20-kw. radio set: requires about 345 sq. ft. of floor space, weighs about 12,500 lb., generates at 120,000 cycles, depends upon concentrated values of inductance and capacity for the determination of its frequency, is excited by current supplied at the frequency of generation, delivers its output at 40,000 volts, and when operating at 80 words per minute must be started and stopped 1200 times a minute.

The 20-kw. commercial high-speed motor-generator set requires about 12 sq. ft. of floor space, weighs about 2500 lb., generates at either 25 or 60 cycles, depends upon the number of its poles and speed of rotation for the determination of its frequency, is excited by direct current, is not ordinarily built in ratings of over 2300 volts output, and operates at practically constant load or at least the changes between no-load and full-load cover an appreciable time.

—Editor.

One of the largest commercial radio equipments employing radiotrons as generators of high-frequency power has recently been built for the United Fruit Company and is now in commercial operation at Tegucialpa, Honduras. This station, together with others of a similar character situated at the proposed locations shown in Fig. 1, is to form a reliable system of communication covering a large part of Central America, and also, when the occasions arise, to form an intermediate radio link between North and South America.

The fundamental circuit of the transmitter is shown in Fig. 2, and is of the master-oscillator power-amplifier type.

The rectifier is of the double-Y type, and equivalent to a six-phase rectifier. This reduces very appreciably the smoothing equipment necessary to minimize the ripple in the direct-current circuit. The master oscillator is designed for operation on either one of two predetermined wavelengths between 2500 and 4500 meters. The radio-frequency power generated by the master oscillator is transferred to the power amplifier unit by the coupling L4.

The power amplifier circuit is in turn conductively coupled to an intermediate or tank circuit which is coupled to the antenna. This tank circuit performs three important functions: it provides a variable coupling to the antenna, thus making possible a very accurate regulation of the output into the antenna; it reduces to a minimum any frequency changes in the output caused by a swinging antenna;

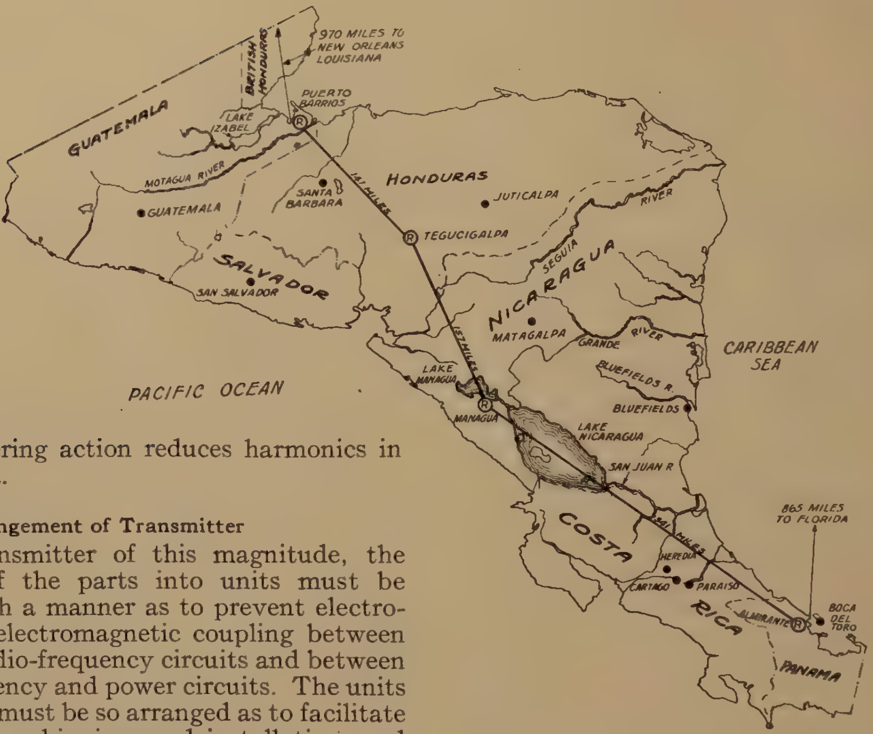


Fig. 1. Map of Central America showing the locations of the initial radio stations which, with others to be constructed, will cover this territory and form a new line of communication between North and South America

and its filtering action reduces harmonics in the antenna.

General Arrangement of Transmitter

In a transmitter of this magnitude, the grouping of the parts into units must be done in such a manner as to prevent electrostatic and electromagnetic coupling between different radio-frequency circuits and between radio-frequency and power circuits. The units themselves must be so arranged as to facilitate manufacture, shipping, and installation, and also to render the transmitter readily accessible, simple to operate, and easy to maintain.

A diagrammatic layout of the transmitter is shown in Fig. 3. The nature of the power supply differs for the several stations, but in every case the filaments of the vacuum tubes are lighted from a small motor-generator set. In this way the possibility of poor regulation of the supply circuit, due to the rapid fluctuation of the load when keying, is avoided. Constant filament voltage is maintained with a corresponding increase in tube life. Unit No. 1 represents this motor-generator set, and Unit No. 2 the starting and regulating panel for this machine.

Both the filament supply and power supply are brought to the control switchboard, shown as Unit No. 3. At this point these sources of power are metered, and from here distributed through the necessary protective devices and switches to the various units in the transmitter.

Unit No. 5 represents the kenotron rectifier. The kenotrons, together with their associated apparatus, are assembled on a skeleton pipe framework, and furnish the d-c. high voltage for the plate circuit of the various

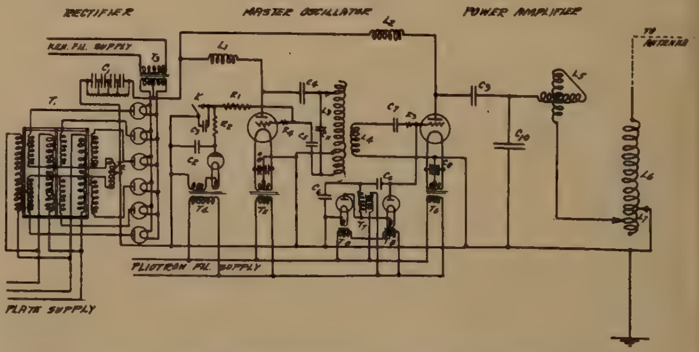


Fig. 2. Elementary Schematic Diagram of Transmitter

T_1 Rectifier plate transformer
T_2 Interphase transformer
T_3 Kenotron filament transformer
T_4 Master oscillator bias unit transformer
T_5 Master oscillator filament transformer
T_6 Power amplifier filament transformer
T_7 Power amplifier bias unit plate transformer
T_8 Power amplifier bias unit filament transformer
R_1 Master oscillator grid leak
R_2 Master oscillator bias protective resistor
R_3 Power amplifier stabilizing resistor
R_4 Master oscillator stabilizing resiistor
L_1 Master oscillator plate choke
L_2 Power amplifier plate choke
L_3 Master oscillator plate inductance
L_4 Grid coupling inductance
L_5 Tank variometer

vacuum tubes. No controls are provided on this unit. A small independent kenotron unit is also mounted on this framework, and furnishes the bias voltage for the 20-kw. tube in the power amplifier.

The first of the radio-frequency units, the master oscillator, is represented by Unit No. 6. Here the radio-frequency current of predetermined frequency is established, transmitted to the power amplifier (Units No. 7, 8, 9 and 10) where it is amplified, and in turn transmitted to the antenna through the outdoor coil Unit No. 12.

The power amplifier is divided into four units: No. 7, the 20-kw. tube with its cooling system, grid leak, choke coils, etc.; No. 9, the intermediate tuning variometer; No. 10, the intermediate circuit air condensers; and No. 8, a control panel for the bias voltage of the 20-kw. tube.

Unit No. 11 consists of a bank of electrically operated high-voltage switches that are used to change taps on the coil of Unit No. 12 for the different wavelength adjustments. Unit No. 4 is mounted on the operator's table, and consists of a group of switches for remote control of the set; from this point the transmitter can be started or shut down.

Types of Vacuum Tubes Used. **(Figs. 4 and 5.)**

Kenotrons. Bias voltage rectifier for master oscillator.
Type of tube: UV-216.
Plate circuit: 20 watts, 350 volts, direct current.
Filament circuit: 2.35 amp., 7.5 volts.

Bias voltage rectifier for power amplifier.
Type of tube: UV-217.

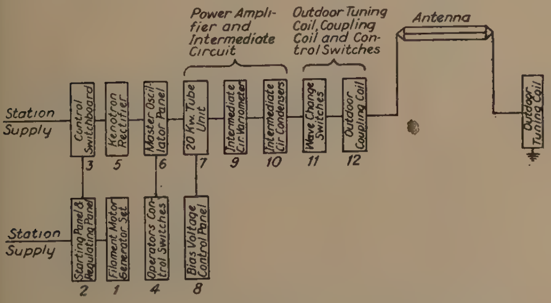

Power Amplifier and Intermediate Circuit
Outdoor Tuning Coil, Coupling Coil and Control Switches
Antenna
Station Supply
Control Switchboard
Kenotron Rectifier
Master Oscillator Panel
20 Kw. Tube Unit
Intermediate Cir. Variometer
Intermediate Cir. Condensers
Wave Change Switches
Outdoor Coupling Coil
Outdoor Tuning Coil
3
5
6
7
9
10
11
12
Station Supply
Starting Panel & Regulating Panel
Filament Motor Generator Set
Operators Control Switches
Bias Voltage Control Panel
2
1
4
8

Fig. 3. Diagram Showing Division of Transmitter into Units

Plate circuit: 150 watts, 1000 volts, direct current.
Filament circuit: 6.5 amp., 10 volts.

Power rectifier.
Type of tube: UV-219.
Plate circuit: 12.5 kw., 15,000 volts, direct current.
Filament circuit: 24.5 amp., 22 volts.

Radiotrons. Master oscillator.
Type of tube: UV-206.
Plate circuit: 1 kw., 15,000 volts, direct current.
Filament circuit: 14.75 amp., 11 volts.

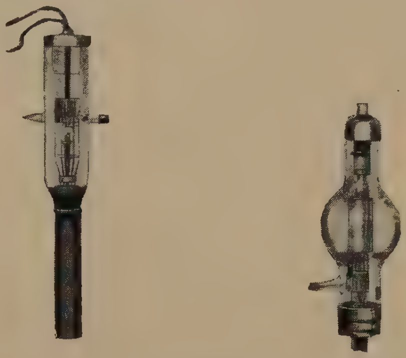


Fig. 4. Pliotron Group of Tubes Used in the Transmitter

Power amplifier.
Type of tube: UV-207.
Plate circuit: 20 kw. 15,000 volts, direct current.
Filament circuit: 52 amp., 22 volts.

Generating Equipment for Filament Supply

In order to attain long life, it is essential that the voltage across the filament of the vacuum tubes be maintained at a constant value. To accomplish this, a separate motor-generator set, shown in Fig. 6, is used.

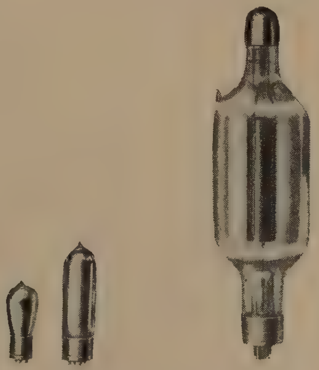


Fig. 5. Kenotron Group of Tubes Used in the Transmitter

Figs. 7 and 8 show a front and back view of the starting and regulating panels for this machine. The line contactor, which is controlled by the push button mounted on the starting panel, is located at the upper right-hand side; the two series accelerating contactors to the left. A switch for disconnecting the generator field is located to the right of the line fuses.

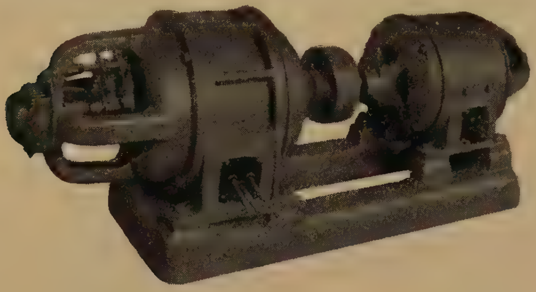
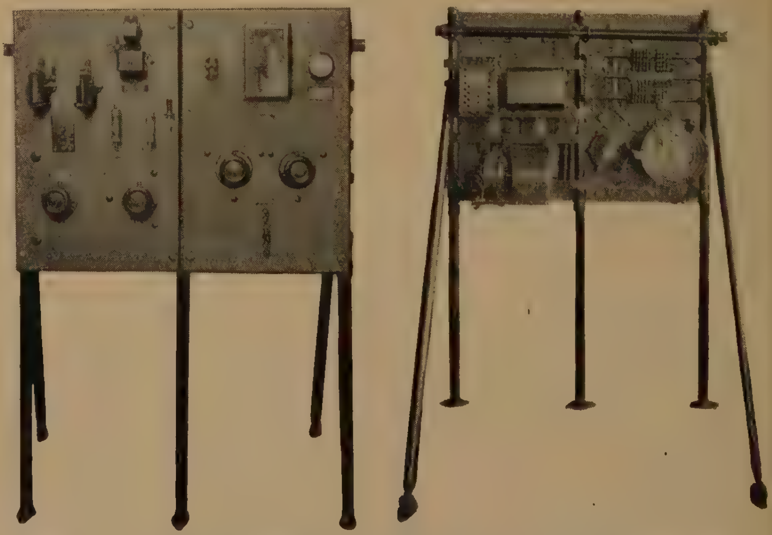


Fig. 6. Filament Lighting Motor-generator Set

Rheostats are provided for both the motor and generator field.

The panel to the right of the starting panel is devoted to the voltage regulating equipment. In this arrangement a small "regulator motor," equipped with dynamic braking, is mounted on the rear of the panel. It is electrically arranged to float with its armature in series with the generator field, and its field windings together with suitable resistors, across the busbars supplying the generator field. The regulator relay, shown on the front view, at the top of the panel, is excited through a suitable transformer from the armature of the generator; its contacts are arranged to short circuit the field of the regulator. Thus with a fluctuating voltage this field winding will be alternately excited and short circuited, varying the counter electromotive force of the regulator motor, and consequently the voltage of the filament generator. A meter is provided on the panel to measure generator voltage, a double-throw switch to reverse the contacts of the regulating relay, and a switch to throw from automatic to hand control. Two rheostats are provided in the field of the generator, one for large steps and one for fine adjustment.



Figs. 7 and 8. Front and Back Views of the Starting and the Voltage Regulating Panels for the Filament Lighting Motor-generator Set

Control Switchboard

Front and rear views of the control switchboard are shown in Figs. 9 and 10. Meters indicate the line voltage and watts, the filament voltage of the power amplifier tube, filament voltage of the kenotrons, filament generator voltage, and alternating-current line amperes. The plate and filament supply circuits are controlled by contactors mounted on the back of the panel and operated by pull switches. A three-pole lever switch disconnects the line from the set and two double-pole lever switches disconnect the radiotron filament and kenotron filament circuits. Individual rheostat adjustment is provided for both of these circuits; and when the main power is taken from a local generating equipment, a field rheostat makes possible the control of this machine. The incoming power line is protected by fuses, so also are all circuits from this unit with the exception of the plate circuit to the rectifier which circuit is protected by relays operating on the plate-circuit contactor.

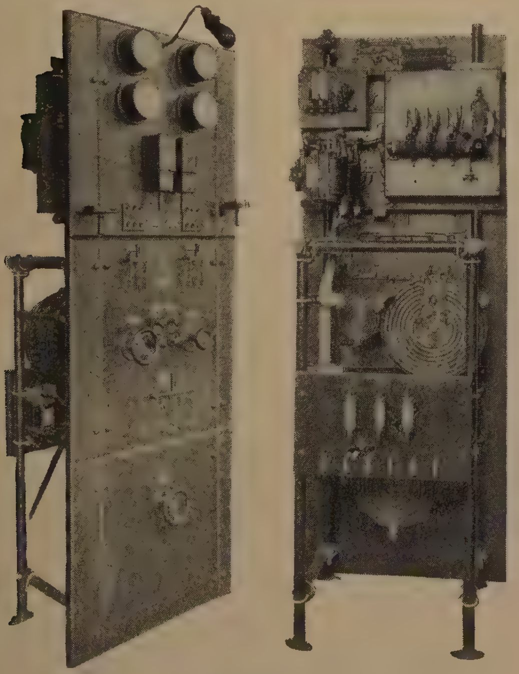
In order to prevent the existence of radio-frequency currents in the control circuits, it is necessary to wire this unit, as well as all other control circuits in the set, with lead covered cable.

Rectifier

The circuit of the rectifier is shown in Fig. 11. Briefly, it consists of a plate transformer, an interphase transformer, a filament transformer, and the rectifier tubes. A filter consisting of condensers is used to reduce the ripple in the direct-current output.

The plate transformer is a three-phase unit the secondary of which is connected to form a double Y. The interphase transformer is connected between the mid-points of the two "Y's." The mid-point of the interphase transformer is the negative terminal of the rectifier output, while the mid-point of the filament supply is the positive terminal. It is thus evident that if the negative terminal be grounded the filament transformer secondary must be insulated for full rated direct-current voltage to ground.

Fig. 12 shows the theoretical voltage wave for the double-Y rectifier and Fig. 13 shows the relations between the voltage from each Y and the output voltage.



Figs. 9 and 10. Front and Back Views of the Control Switchboard

The current wave in each secondary winding will be a square wave equal in magnitude to one-half the direct-current output, and flowing for one-third of a cycle. This is true only in the double-Y type of rectifier with interphase transformer and with no resistance or reactance in the plate transformer. The effect of reactance in the plate transformer is to increase the time during which the current flows. In the design of a rectifier this effect is usually neglected, as it has little influence until the limit of emission for the kenotron is reached.

The first term in the voltage equation (Fig. 12) represents the direct-current component of the rectified wave. From this it is possible to specify the secondary alternating-current voltage for the plate transformer to give the desired direct-current voltage.

$$\text{Alternating-current secondary volts} = \frac{0.707}{0.827} \times \text{no-load direct-current voltage.}$$

The change in voltage from no load to full load is given by:

$$e_{d\text{-}c.} = \frac{\text{space charge} + \text{transformer loss}}{\text{direct current}}$$

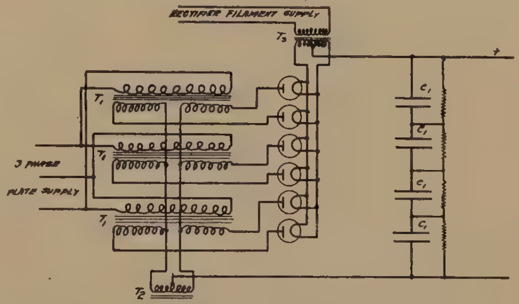


Fig. 11. Schematic Diagram of Double-Y Rectifier

T1 Plate transformer
T2 Interphase transformer
T3 Filament transformer
C1 Smoothing condensers

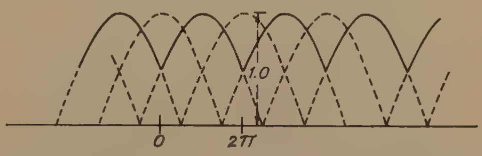


Fig. 12. Theoretical Three-phase Rectified Voltage Wave

$$y=\frac{3\sqrt{3}}{2\pi}-\frac{3\sqrt{3}}{8\pi}\cos\theta-\frac{3\sqrt{3}}{35\pi}\cos 2\theta-\frac{3\sqrt{3}}{80\pi}\cos 3\theta\ldots\frac{3\sqrt{3}}{-\pi(9m^2-1)}$$
$$\cos m\theta\ldots=0.827-0.207\cos\theta-0.0472\cos 2\theta-0.0207\;3\theta-0.0112\cos 4\theta-0.0074\cos 5\theta\ldots$$

The space charge loss depends on the type of kenotron used, filament temperature, direct current through each tube, and time the current flows. This loss may be obtained from characteristic curves (space-charge curves) for the kenotron used. The transformer loss is the sum of the plate transformer and interphase-transformer losses.

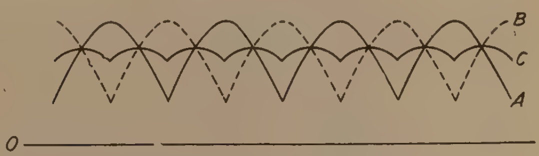


Fig. 13. Output Voltage Wave of Double-Y Rectifier

A Voltage from first set of phases
B Voltage from second set of phases
C Output voltage of rectifier

The alternating-current secondary voltage to deliver the desired voltage at full load is then:

$$\text{A-c. voltage effective} = \frac{0.707}{0.827} \times (E_{d\text{-}c.} + e_{d\text{-}c.})$$

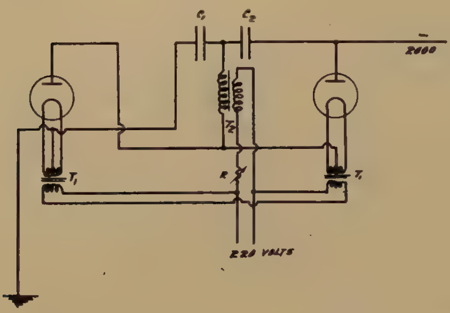


Fig. 14. Schematic Diagram of Bias Rectifier for 20-kw. Power Amplifier

R_1 Voltage control rheostat
T_1 Filament transformer
T_2 Plate transformer
C_1 and C_2 Smoothing condensers

The regulation of the rectifier may be obtained from the full-load direct-current voltage and no-load direct-current voltage.

As the secondary current is equal to one-half the direct current and flows for one-third of a cycle, the secondary effective current will be:

$$I_{sec.} = \frac{1}{2\sqrt{3}} \times I_{d\text{-}c.}$$

Figs. 15 and 16. Front and Side Views of the Kenotron Rectifier

To obtain the best operating conditions the leakage reactance between primary and secondary windings should be kept a minimum. This may be accomplished by winding the primary in two parallel sections, and winding one-half of the secondary over each of these primary coils. The same result may be obtained by interleaving the primary and secondary windings.

If there are two primary windings per phase in parallel, the primary current for each section will be :

$$I_{prim.} = N\sqrt{2/3} \times I_{d\text{-}c}$$

where N is the voltage ratio between the primary and secondary windings.

The interphase-transformer voltage is represented by the odd harmonic components of the equation in Fig. 12. However, due to transient conditions during the periods of current transfer between tubes, the interphase-transformer voltage will be higher than that calculated from the odd-harmonic component. The equation for the interphase-transformer voltage is therefore:

$$E_{interphase} = 0.5\, E_{d\text{-}c.}$$

The interphase-transformer current is one-half the direct current.

The exciting current of the interphase transformer adds to the kenotron current and consequently should be kept low, usually about three per cent of the direct current.

The ripple in the direct-current voltage from a double-Y rectifier is the percentage variation on either side of the average value. With no smoothing, the ripple is approximately 6 per cent. The reduction in ripple due to the filter may be taken approximately as the ratio of the ripple current at the beginning of the filter to the ripple current in the last section, and is expressed by

$$\frac{I_N}{I_O} = \frac{1}{(LCw^2-2)N} \text{(approx.)}$$

where N is the number of sections in the filter.

For economic reasons it is usually desirable to build a high-voltage filter in a single section, unless the ripple is to be reduced to an extremely low value. For a single section the magnitude of the ripple may be expressed as:

$$\text{Per cent ripple} = \frac{1}{(LCw^2-1)} \times \text{per cent ripple}$$

with no smoothing.

In low and medium power rectifiers, the inductance of the plate transformer is of such magnitude that a bank of condensers of proper value shunted across the output will reduce the ripple to one per cent or less.

In these transmitters a small 2000-volt rectifier is required to supply the bias voltage for the power amplifier tube. This rectifier is built into the power rectifier and is designed for single-phase full-wave rectification. Fig. 14 shows the circuit used. The connections put the two rectifier tubes in series, thus making possible the use of 2000 volts without exceeding the rating of the UV-217 kenotrons.

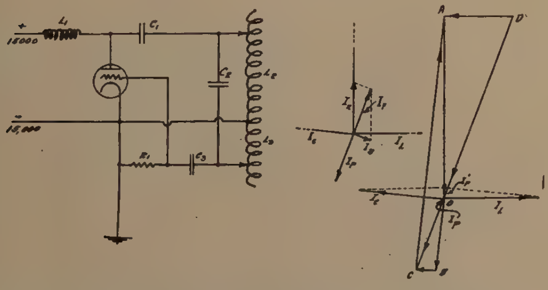


Fig. 17 (left). **Elementary Schematic Diagram of Master Oscillator Circuit**

(Right). **Vector Diagram of Voltage and Current Relations in Master Oscillator Circuit**

R_1 Grid leak
L_1 Plate choke
L_2 Plate tank inductance
L_3 Grid tank inductance
C_1 Plate blocking condenser
C_2 Tank condenser
C_3 Grid blocking condenser

The rectifier is built up on a skeleton pipe framework as shown in Figs. 15 and 16. Each tube is locked into its contacts by means of a spring catch on the upper holder. Immediately behind the lower bank of tubes is the transformer which supplies the plate circuit of the kenotrons. Just back of the plate transformer is the interphase transformer. Above the plate transformer and immediately behind the kenotrons is the filament transformer which, as explained, is insulated for the full 15,000 volts direct current.

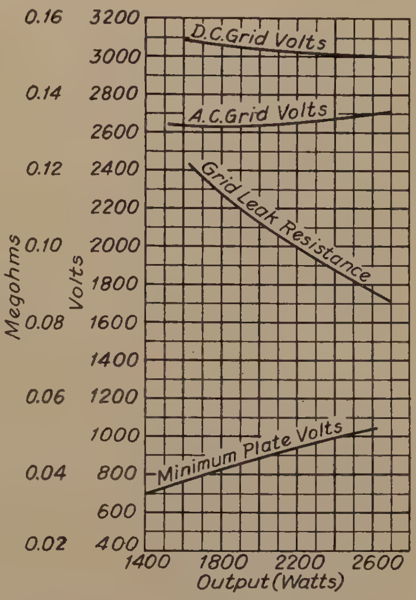


Fig. 18. **Curves of the Calculated Optiminum Operating Conditions for a UV-206 Tube Operating at 15,000 Volts Direct Current**

The instrument transformer for the filament voltmeter is incorporated in the same case.

The condensers forming the smoothing circuit are mounted back of the filament transformer. The total capacity of this unit is 0.6 m.f. As these condensers are connected in series it is necessary to balance the voltage across them with resistors. These are mounted with suitable brackets directly on the studs of the condensers. In addition to this function, these balancing resistors also serve as a multiplier for the direct-current voltmeter shown at the front of the rectifier.

Master Oscillator

The master oscillator employs one UV-206 radiotron for the generation of high-frequency power for exciting the power amplifier.

Referring to the vector diagram, Fig. 17: *OD* represents the alternating-current voltage output of the tube and may be resolved into its two components—*AD* which is the drop across the plate blocking condenser, and *AO* the alternating-current voltage across the inductance between plate and filament taps. This inductance is a portion of a parallel resonant circuit. *OC* represents the alternating-current grid voltage on the tube and may be resolved into its two components *OB* and *BC*. *OB* is the alternating-current voltage across the inductance between filament and grid taps, and *BC* the resistance drop in the grid coil. *AC* represents the voltage across the condenser C_2, and *Ic* the current in this condenser. I_e is the current in the inductances L_2 and L_3. *Ip* is the alternating-current plate current to the tube and may be resolved into its two components *Ir* and *Is*. *Ir* is the feed current to the tuned circuit C_2, L_2, L_3. *Is* is the current in the plate choke *L*.

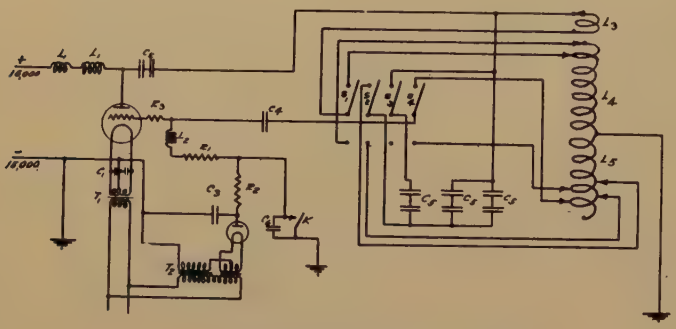
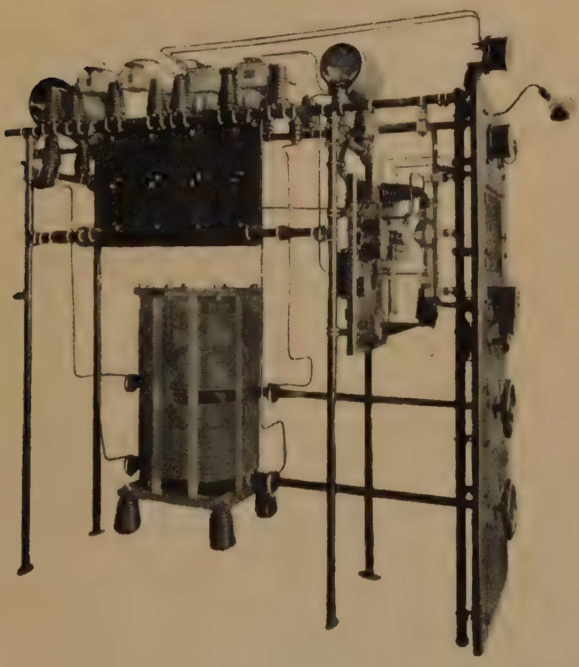
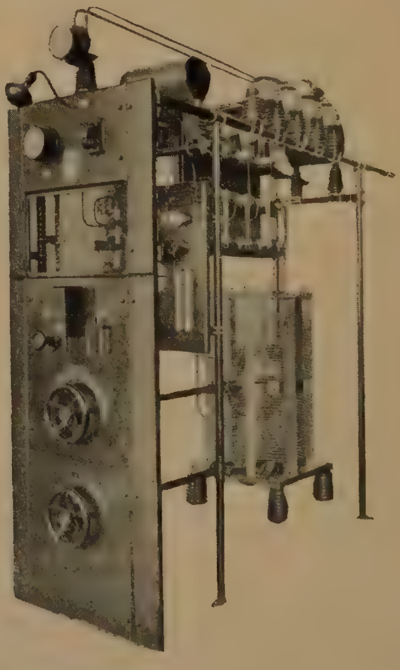


Fig. 19. Schematic Diagram of Master Oscillator

R_1	Grid leak
R_2	Bias protective resistor
R_3	Grid series resistor
L_1	Plate choke
L_2	Grid choke
L_3	Variometer rotor
L_4	Plate coil of tank
L_5	Grid coil of tank
C_1	Filament by-pass condenser
C_2	Plate blocking condenser
C_3	Bias smoothing condenser
C_4	Grid blocking condenser
C_5	Tank condenser
C_6	Keying condenser

In the following calculations the assumption is made that the alternating-current voltage across the condenser C_2 is equal to the arithmetical sum of the plate alternating-current voltages, and grid alternating-current voltage. As the angle *DOA* is ordinarily only a few degrees, this assumption introduces only a very small error. The alternating-current plate and grid voltages may be obtained by reference to the optimum operating curves for the tube, Fig. 18. The alternating-current grid voltage may be read directly, while the alternating-current plate voltage is found from the following relation:





Figs. 20 and 21. Side and Front Views of Master Oscillator

A.-c. plate volts = (d-c. plate volts − minimum plate volts) × 0.707.

The condenser current is then:

$$Ic = \frac{\text{A-c. plate volts} + \text{a-c. grid volts}}{\dfrac{1}{2\pi f C_2}}$$

where f = the operating frequency.

I_c is chosen so that the circulating volt-amperes in the circuit $C_2L_2L_3$ is equal to 4π times the watts in this circuit. In the case of a master oscillator of the type used other factors influence this ratio. The circulating current is limited by the maximum coupling which may be allowed between the grid circuit of the power amplifier and master-oscillator tank circuit. If the coupling be too great, the power amplifier will oscillate as a tuned grid oscillator, and the master oscillator will no longer control the frequency.

With C_2 known, the required inductance $L_2 + L_3$ may be determined from:

$$L = \frac{\lambda^2}{C_2\,(1884)^2}$$

where λ is the wavelength in meters.

The total inductance is then divided in such proportions that:

L_2 is to L_3 as alternating-current plate volts is to alternating-current grid volts.

In order to obtain minimum tube losses and best operating efficiency, it is necessary to have the plate and grid alternating-current voltages exactly 180 deg. out of phase. This condition is obtained by the proper choice of plate blocking condenser and plate choke.

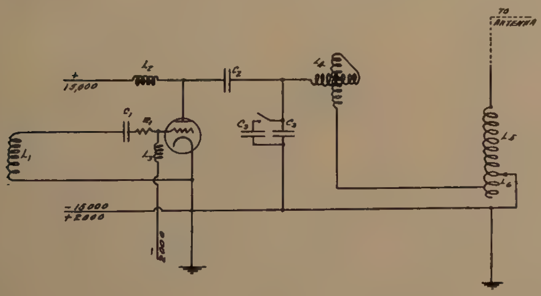


Fig. 22. Schematic Diagram of Power Amplifier

R_1	Stabilizing resistor
L_1	Grid coupling condenser
L_2	Plate choke
L_3	Grid choke
L_4	Tank variometer
L_5	Antenna loading coil
L_6	Tank antenna coupling
C_1	Grid blocking condenser
C_2	Plate blocking condenser
C_3	Tank condensers

In the oscillating circuit we have the following:

Since OB and OC are parallel

$$\text{angle } OAC = \text{arc sin } \frac{CB}{OA}$$

$$\frac{OA}{\sin C} = \frac{OC}{\sin A} = \frac{AC}{\sin O} \text{ from which angle } OCA$$

may be obtained.

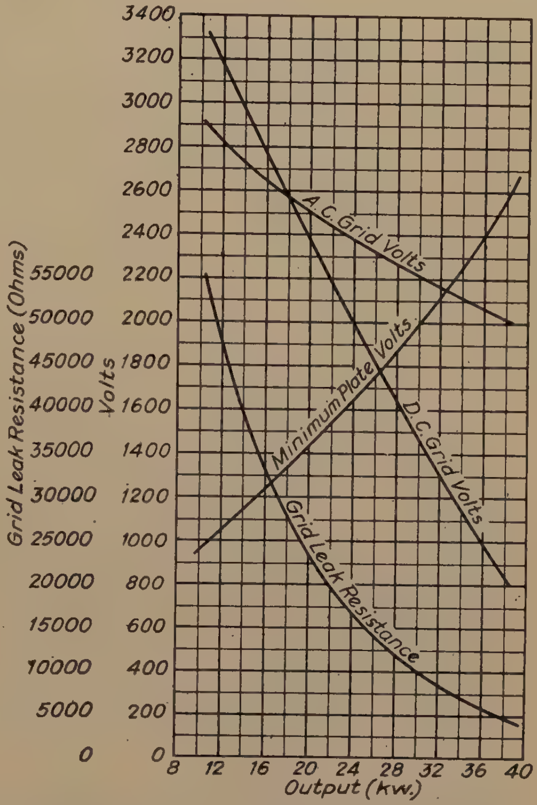


Fig. 23. Curves of the Calculated Optimum Operating Condition; 20 kw. at 15,000 volts direct current

Knowing angles OAC and OCA, we may solve for angle AOC and its supplement angle AOD.

$AD = (OD \text{ a-c. plate volts}) \times \sin AOD.$

Since AD is the alternating-current drop across the plate blocking condenser, we may now calculate the value of the plate blocking condenser required, provided the condenser current is known. The condenser current is calculated on the assumption that it is the unity power-factor current necessary to give the load watts at the alternating-current plate voltage. This is shown as Ir on Fig. 17

$$Ir = \frac{\text{watts output}}{\text{A-c. plate voltage.}}$$

From which

$$Xc = \frac{AD}{Ir} \text{ and } C1 = \frac{1}{2\,f Xc}$$

The product of the condenser current and voltage drop across the condenser is $Ir \times AD$. The plate choke is now calculated so that the product of its current times the drop in voltage across it is equal to the same value; this assumes full plate voltage across the choke coil.

The grid leak resistance R_1 is obtained directly from the optimum operating curves in Fig. 18. The grid condenser is not critical and may be taken as 20 or 30 times the capacity between the grid and plate of the tube.

The complete circuit is shown in Fig. 19, including the keying system and wave-change switches used on the master oscillator. As these sets are to operate at one wavelength normally, with a second predetermined wavelength to be used if needed, no provision for a rapid wave-change is necessary. Manually-operated switches are therefore used as described later. In the diagram, S_1 changes the plate tap, S_2 the tank tap, S_3 the tank capacity, and S_4 the grid tap. It will be noted in Fig. 19 that an inductance L_3 has been added. This is in the form of a variometer rotor on one end of the tank coil and provides for fine adjustment of the wavelength.

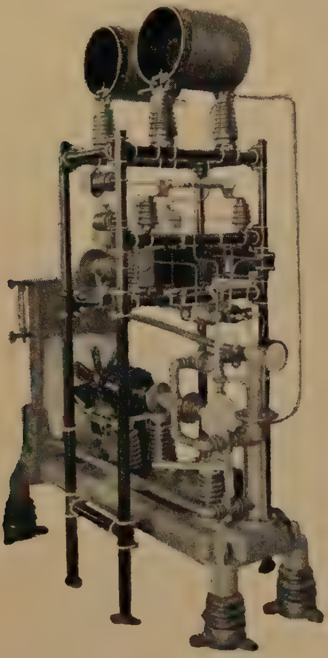


Fig. 24. Front View of 20-kw. Tube Unit

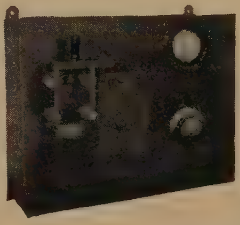


Fig. 25. Control Panel for Power Amplifier Bias Voltage

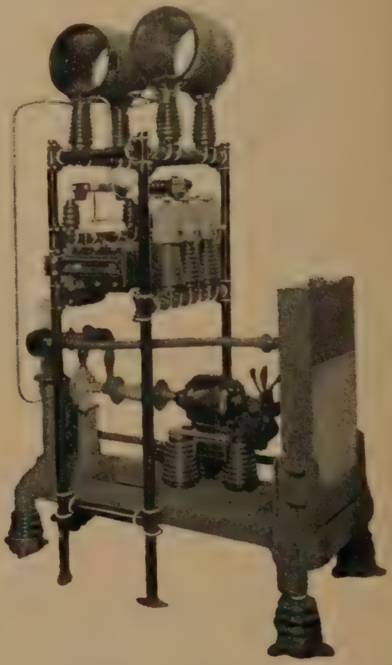


Fig. 26. Back View of 20-kw. Tube Unit

The keying system incorporates a small kenotron rectifier tube used in conjunction with a transformer to provide a negative bias for the master oscillator tube when the key is up.

The master oscillator is built up on a pipe framework immediately back of a 90-inch control board. This unit is shown in Figs. 20 and 21. The tube, together with its grid condenser, grid choke, grid resistance, etc., is mounted on a sub-panel back of the main control panel.

Behind the sub-panel and clear of all framework is the tank inductance and power amplifier grid coupling coil. This unit is made up of edgewise-wound copper strip, mounted on a treated maple framework. The upper rotor is the coupling coil to the power amplifier. The lower rotor, which acts as a vernier on the tank inductance, is formed of edgewise wound copper strip. Great care has been used to prevent excessive voltage gradients and to avoid metal parts in close proximity to the field of the coil. The controls for the two rotors are brought out to the front of the main panel, and are capable of being locked in any position.

The tank condensers are mounted at the top of the framework above the coil. Between the coil and the condensers are four single-pole double-throw switches which are used to change the connections of these units for operation at different frequencies. The two choke coils in the plate circuit of the master oscillator are wound on porcelain forms which are mounted on the top of the pipe framework.

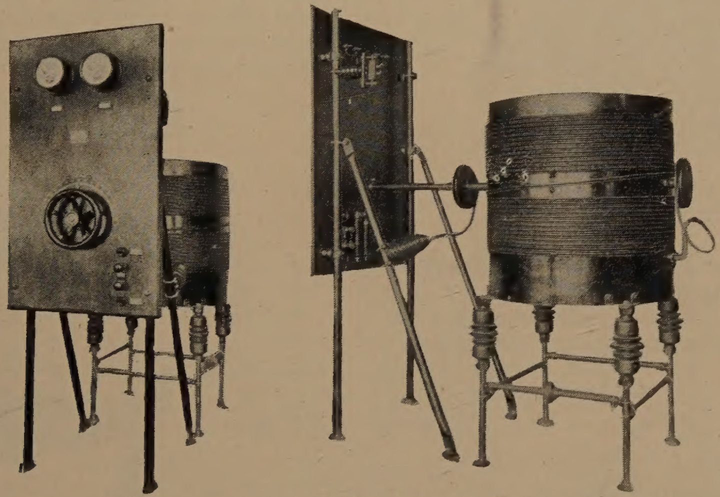
Meters indicate the current in the tank circuit and the filament voltage of the master oscillator tube. The overload relay in the plate circuit of the master oscillator is shown on the middle panel of the board, together with the filament rheostat and filament switch. The keying relay is mounted at the top of the panel.

the tank antenna coupling inductance L_6 and the antenna loading inductance L_5. This mutual inductance will then be given by

$$M=\frac{E_r}{2\pi f\, I_t}$$

where I_t is the tank current.

The tank circuit may be calculated as a simple parallel tuned circuit, having full plate alternating-current voltage across it. The condenser and inductance are made to have the same reactance, which reactance is equal numerically to the alternating-current plate voltage divided by the tank current.



Figs. 27 and 28. Front and Rear Views of Intermediate Circuit Variometer

Power Amplifier

The circuit for the power amplifier, including one antenna tuning coil, is shown in Fig. 22. It consists essentially of one 20-kw. pliotron with its cooling system, plate and grid blocking condensers, filament transformers, tank inductance, and tank capacity.

In proportioning the units in this circuit, it is best to start with the antenna, as this must in all cases be known.

The antenna current Ia, for any type of antenna, is:

$$Ia=\sqrt{\frac{\text{watts in antenna}}{\text{antenna series resistance}}}$$

The voltage that the tank current must induce in the antenna is the resistance component of the antenna voltage, and is given by the expression:

$Er=Ia\times$antenna series resistance.

This voltage is proportional to the tank current and the mutual inductance between

The alternating-current plate voltage, alternating-current grid voltage, and direct-current grid voltage for the 20-kw. tube may be obtained from the curves in Fig. 23.

The plate blocking condenser should be so proportioned that it causes but small drop in voltage to the power current in the tank circuit. The plate choke is then calculated to draw the same value of lagging volt-amperes that the plate blocking condenser draws leading volt-amperes.

The 20-kw. tube unit and the bias control panel are shown in Figs. 24, 25, and 26. The tube itself is mounted in a cast water jacket and clamped into place by a handwheel at the top of the jacket. This wheel also acts as a corona shield to relieve the voltage strains on the glass upper portion of the tube. By means of a single lever, the intake and outlet valves of the jacket can be connected to the cooling system, which consists of a rotary pump, radiator, and cooling fan.

The motor driving the pump also drives the fan. The lever which operates the valves to the water jacket also serves as a switch for connecting the voltage to the plate of the tube, so that it is impossible to put voltage on the tube when these valves are closed. A third valve mounted above and to the right of the pump permits the operator to shunt the cooling water around the pump thus changing to thermo-syphon cooling. A flow indicator is provided in the piping and a thermometer in the discharge side of the water jacket. As the radiator, frame, and piping are at plate potential, the complete cooling unit is mounted on insulators. The equipment immediately associated with the 20-kw. tube is mounted on a pipe framework independent of but erected over this unit.

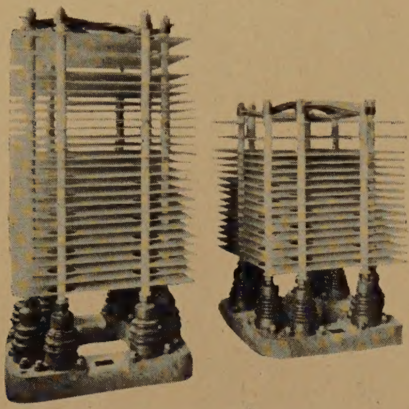


Fig. 29. Intermediate Circuit Air Condensers; 0.003 micro-farads on left and 0.002 micro-farads on right

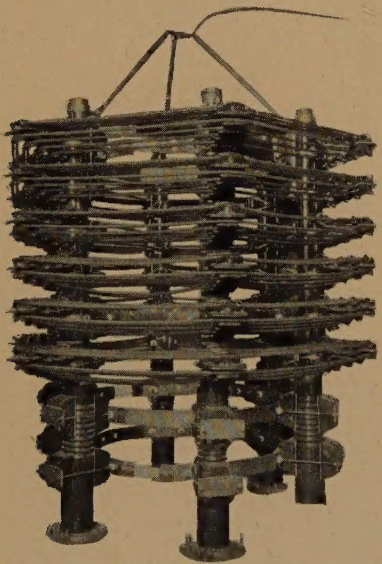


Fig. 30. Tuning Coil

Intermediate Circuit

The intermediate circuit, or tank variometer, is shown in Figs. 27 and 28. The stationary coil of the variometer is wound with high-frequency cable on a heavy insulating form. Adjacent turns are spaced with ¼-in. treated hemp rope. The rotor is built up in a similar manner. The variometer is supported on a pipe framework from which it is insulated by porcelain insulators. This framework has been provided with an insulating coupling in its only closed loop, to prevent the existence of induced currents.

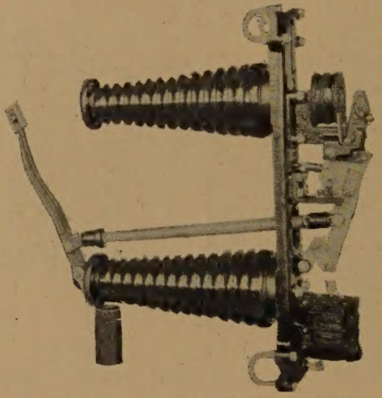


Fig. 31. Electrically Operated Wave-change Switch, 45,000 volts

The control for this variometer is brought out to a panel furnished with a calibrated scale and a device to lock it in any setting. Below the variometer handwheel are two pull switches for operating the wave-change switches. These are provided with signal lights that indicate when all of the switches corresponding to one wavelength position are closed. One of the two meters shown indicates the current in the power-amplifier tank circuit, and the other, the antenna current.

The air condensers used in the intermediate circuit of the power amplifier are shown in Fig. 29.

Antenna Coupling and Tuning Coils

The general constructional details of the tuning coils are shown in Fig. 30.

Wave-change Switches

When changing from one wavelength to another, it is necessary to change two taps on the antenna coupling coil and one tap on the tuning coil. The switches used for this purpose are shown in Figs. 31 and 32. Four are required on the coupling coil, and two on the tuning coil. These switches vary in voltage rating, depending upon the constants of the antenna with which they are used. Auxiliary switches are provided which signal back to the station the position of the switches. All switches closed or opened simultaneously have their auxiliary contacts connected in series.

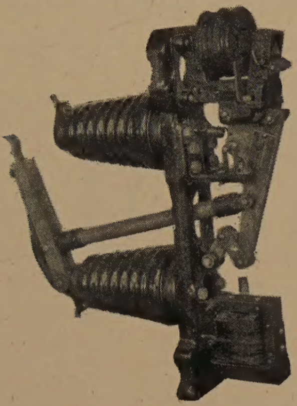


Fig. 32. Electrically Operated Wave-change Switch, 25,000 volts

Operator's Control Switches

A small switch box, Fig. 33, is provided for mounting on the operator's table, which enables him to start or stop the motor-generator set supplying all filament circuits, to open or close the supply to all filament circuits, and to open or close the supply to plates of all tubes. A red signal light is illuminated when the plate supply is closed.

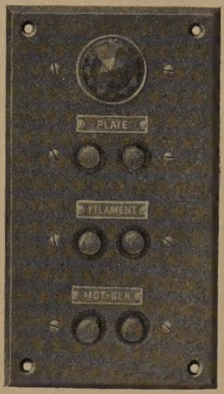


Fig. 33. Operator's Control Switches

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Circuit Breakers

Some Features of Importance in Circuit Breaker Design. Read, E. K.
Elec. Jour., Nov., 1923; v. 20, pp. 408-410.

Converters, Synchronous

Shunt Operation of Rotary Converters in Substations Effective. Saulsbury, R. J.
Elec. Rwy. Jour., Nov. 10, 1923; v. 62, pp. 815-817.
(Experiences of the Pittsburgh Railways.)

Electric Cables

Cleveland 66-kv. Cable Joint. Wallau, H. L.
Elec. Wld., Nov. 24, 1923; v. 82, pp. 1058-1061.
("Investigation and extensive tests of wrapped joints and of joints insulated with tubes and compound.")

Electric Controllers

Principles of Alternating Current Control. Fox, Gordon.
Power Pl. Engng., Nov. 15, 1923; v. 27, pp. 1138-1141.
(Serial.)

Electric Distribution

New Electric Distribution System.
Elec. News, Nov. 1, 1923; v. 32, pp. 43-45.
(Describes a new underfloor system giving great flexibility of distribution at low cost.)

Electric Drive—Pumps

How Electric Motors Should be Applied to Pumping Equipment. Rogers, R. H.
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